GENERAL SCIENCE

BEDFORD


GINN AND
COMPANY
Ex Libris

AIRPLANES IN ACTION.

GENERAL SCIENCE

A BOOK OF PROJECTS

BY

EDGAR A. BEDFORD, Sc.D.

HEAD OF THE DEPARTMENTS OF BIOLOGY AND GENERAL SCIENCE
DE WITT CLINTON HIGH SCHOOL, NEW YORK CITY

LECTURER ON METHODS IN TEACHING GENERAL SCIENCE
SCHOOL OF EDUCATION, NEW YORK UNIVERSITY

ALLYN AND BACON

BOSTON NEW YORK CHICAGO
ATLANTA SAN FRANCISCO

PAB

PREFACE

The material of *General Science* is organized according to the project-problem plan. The class projects are broken up into problems, in the solution of which the pupils are led to form hypotheses from their observations, to check and modify these hypotheses by further observations, and finally to come to a conclusion which is of value in the development of the project.

The following aims have been kept in mind:

First: to encourage the spirit of inquiry, and to cultivate the attitude of independent judgment, of openmindedness, and of reliance upon facts.

Second: to put the pupils in possession of certain fundamental truths which give an explanation of many everyday activities.

Third: to lead pupils to a broad view of the forces that affect their surroundings, rather than a detailed study of some one section of their environment. The pupils of this early adolescent period are interested in big units and a broad outlook, rather than in minute details.

The material has been selected from that part of the environment which is related to the practical interests of the pupils. No material has been included merely because it helps in developing some scientific generalization. The needs of the ordinarily well-educated citizen, rather than the

needs of the scientist, have influenced the choice of topics. Preference has been given to topics which lead to the understanding of phenomena of large economic importance.

The environment has been considered as a whole, not as made up of divisions which can be classified as physics, chemistry, biology, astronomy, and physiography. In working out a problem for the solution of the project, use is made of any necessary facts, regardless of whether they belong to this or that special division of science.

By means of a large number of suggested individual projects, the teacher is enabled to adapt the course to his special school. Pupils are encouraged to work out the projects that are of the most interest to them. Not all that are listed are to be required of any one student. Some are so simple that any one can perform them easily, while a few appeal only to those who have a decided mechanical bent.

The text carries out the spirit of the recommendations as to general science of the Commission on the Reorganization of Science in the Secondary Schools It is adapted for use in the junior high school, or in the first year of the high school.

The author wishes to express his appreciation to many friends and fellow teachers whose assistance has contributed much in the preparation of this book. Mr. Harry G. Barber, Department of Biology, and Mr. Thomas Currie, Chairman of the Department of Physics, in the De Witt Clinton High School New York City, have read much of the manuscript and have made helpful suggestions and criticisms. The following teachers of general science in the New York City schools, acting with the author in planning a syllabus in general science, have given much valuable advice: Mr. Maurice W. Kearney, Bay Ridge

High School; Dr. Elsie M. Kupfer, Wadleigh High School; Miss Mary Morris, Newtown High School; Miss Ethel Schwarz, Speyer Experimental Junior High School; Miss Emily Topp, Julia Richman High School; and Dr. George C. Wood, Commercial High School.

Mr. George K. Gombarts, Head of Art Department, and Mr. John W. Tietz of Department of Biology, De Witt Clinton High School, have given valuable advice concerning illustrations and have furnished original drawings and photographs.

Dr. Charles F. Brooks of the Weather Bureau, Dr. L. O. Howard, Chief of the Bureau of Entomology, and Mr. W. B. Greeley, Chief of Forest Service, have been generous in opening the resources of their departments.

Superintendent Clarence E. Meleney, Superintendent John L. Tildsley, and Dr. Francis H. J. Paul, Principal of De Witt Clinton High School, by their broadness of view and educational vision, have been sources of stimulation in the development of the course represented in the book.

To his wife, Leila Hoge Bedford, the author desires especially to express his indebtedness for her intelligent and painstaking assistance.

E. A. B.

TABLE OF CONTENTS

Suggested individual projects, reports, and references are not listed here, but may be found at the end of most projects.

UNIT I

RELATION OF AIR TO EVERYDAY ACTIVITIES

UNIT II

RELATION OF WATER TO EVERYDAY ACTIVITIES

UNIT III

THE RELATION TO US OF SUN, MOON, AND STARS

UNIT IV

WORK AND ENERGY

UNIT V

RELATION OF SOIL AND PLANT LIFE TO EVERYDAY ACTIVITIES

LIST OF ILLUSTRATIONS

ACKNOWLEDGMENTS OF ILLUSTRATIONS

Brownlee and Others' Chemistries, No. 29, 30, 52, *a* and *b*, 53, 54, 55, 60, 66, 70, 73, 102, 161, 162, 206.
Chicago, Milwaukee, and St. Paul R. R., No. 113.
Columbia Graphophone Company, No. 44, 45.
Ford Motor Company, No. 214, 245.
Forest Service, U. S. Dept. Agriculture, No. 39, 61, 65, 68, 69, 85, 86, 92, 95, 97, 105, 106, 109, 112, 121, 125, 134, 135, 137, 177, 183, 248, 250, 251, 252, 253.
General Electric Company, No. 26, 111, 115, 188, 189, 204.
Grand Trunk R. R., No. 256.
Harvey Conard, Hollis, New York, No. 239.
John Reiss, New York City, No. 21.
Leon Barritt, Brooklyn, New York, No. 154.
New York Board of Health, No. 87, 88.
New York Zoological Society, No. 475.
National Lamp Works, General Electric Company, No. 215, 216, 217, 218, 227, 228, 229, 230, 234.
Packard Motor Company, No. 1, 187.
Pacific Northwest Tourist Association, No. 257.
Pennsylvania Lines, No. 136.
Signal Corps, American Expeditionary Force, No. 11, 192, 200.
Thomas Edison, Inc., No. 46, 47.
U. S. Bureau of Chemistry, No. 57, 67.
U. S. Bureau of Entomology, No. 63, 287, 288, 293, 295, 296.
U. S. Bureau of Standards, No. 219, 221, 222, 223, 224, 225, 226.
U. S. Dept. of Agriculture, No. 81, 82, 84, 263, 264, 265, 266, 267.
U. S. Geological Survey, No. 50, 58, 59, 72, 74.
U. S. Naval Observatory, No. 151.
U. S. Reclamation Service, No. 98, 99, 100, 101, 114.
U. S. Weather Bureau, No. 6, 8, 34, 35, 36, 37, 38, 41, 90, 91, 93, 94, 103.
U. S. Navy, No. 42.
Weston Electrical Instrument Company, No. 193, 195, 201, 205.

GENERAL SCIENCE

UNIT I

RELATION OF AIR TO EVERYDAY ACTIVITIES

PROJECT I

IMPORTANCE OF THE WEIGHT OF AIR

For many centuries men who experimented with the problem of keeping a body heavier than air moving through it as a bird flies were the objects of ridicule and derision. Only so short a time ago as 1905, the first successful flying machine was invented by Wilbur and Orville Wright of Dayton, Ohio.

Now, after invaluable service in the Great War, the airplane in a highly perfected stage has crossed the Atlantic Ocean. It has crossed our continent, a distance of 3000 miles, in 25 hours of actual flying time. One of man's greatest ambitions has become a reality, and without doubt the future holds further achievement in the development of the airplane as wonderful as that of the last few years.

Problem 1. How an airplane remains in the air. — The study of the kite may help us to understand the airplane. Is it possible to fly a kite on a day when there is no wind? In starting to fly a kite, does a boy run with or against the wind? Is running necessary to start the kite on a day when a strong wind is blowing? What happens if the string

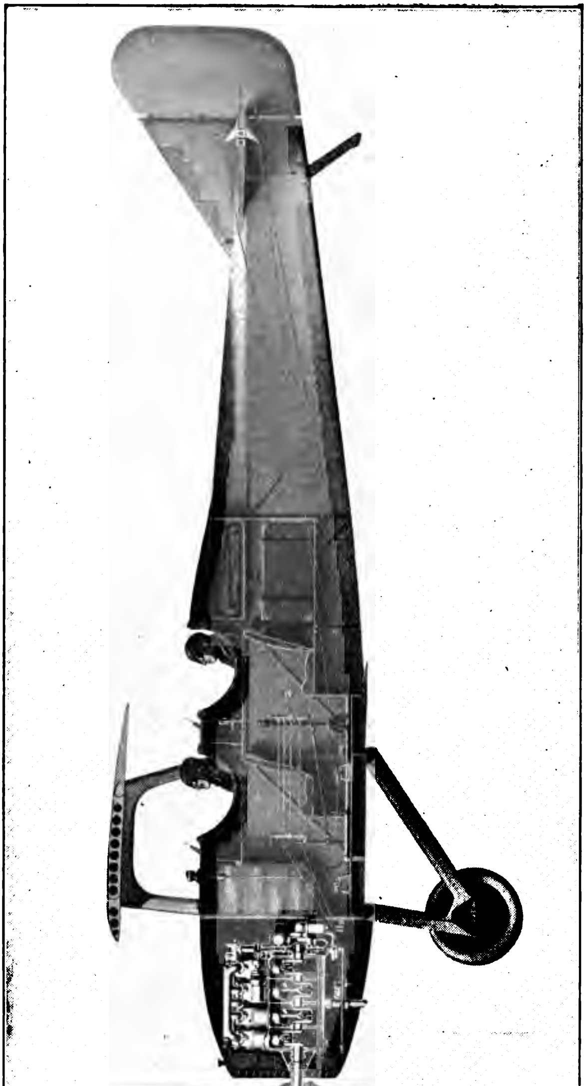


Figure 1.—Sectional View of an Airplane.

breaks? What is the purpose of the tail of the kite? As a result of a consideration of these questions, it will be understood that a plane or flat surface, if held at the proper angle, is kept up by the force exerted by the air in motion.

That air in motion has great force, is well known to us. The destruction caused by a severe wind is sufficient proof

FIGURE 2. — AIRPLANE IN AIR.

of this. We are also familiar with the fact that even when there is no movement of the air, the same force is exerted if an object is passing rapidly through the air. A ride on the front seat of a street car or in a rapidly moving automobile convinces us of the force which may be considered to be exerted either by the moving body or by the air.

The *airplane* with its light, high power engine is able by means of its propellers to attain great speed through the

air. The planes may be so controlled that they present the proper angle to the air. The same force is exerted if the machine is moving 75 miles per hour, as if the machine were

FIGURE 3. — UNITED STATES AIRPLANE.

Photographed on the flying field at Tours, France. Explain the appearance of the propeller and the dust cloud behind and to the left of the machine. Note the slant of the planes.

stationary and the air were moving 75 miles per hour. It will thus be seen that the airplane remains in the air for the same reason that a kite remains in the air.[1]

Problem 2. Has air weight? — As the propeller of the airplane drives the machine through the air very much as the propeller of a boat drives it through the water, air seems to be a substance, just as water is. If this is true, it should have weight. *Weight* is the measure of the pull of the earth (gravity) upon particles composing various

[1] Many pupils will want to make model airplanes. At the end of the chapter references are given which will provide directions as to the details of their construction.

materials. The weight of a book is the measure of the pull of the earth upon the book. If we drop it, it falls or is pulled toward the center of the earth. How may we discover that air has weight? The following experiment has been tried many times.

FIGURE 4.

Experiment.—Weigh carefully a strong flask; then by means of an air pump remove the air from it and weigh it again. What is the result? That air has weight, may also be shown by blowing up a basket ball or football as full as possible, then weighing it (Figure 4), and after allowing the air to escape, weighing it again (Figure 5).

Careful weighing has shown that one cubic foot of dry air at sea level and at the freezing temperature (of water) weighs about one thirteenth of a pound. Calculate approximately the weight of the air in the schoolroom; in your bedroom, etc.

FIGURE 5.

Problem 3. Does air press upon things? — If air has weight, it should exert pressure upon everything; because the atmosphere extends many miles above the earth's surface.

Experiment. — Into a tin can which has a small opening, put a few spoonfuls of water. Heat the can until sufficient steam is formed to drive out the air. Plug the opening in the can with an airtight stopper. As the can cools, the steam changes back to water and the space within the can contains neither steam nor air and is called a *vacuum*.

What happens to the can? Explain.

Use a wide-mouthed bottle instead of the can and in place of the stopper tie a piece of paper or still better a piece of sheet rubber over the opening. Result? Conclusion?

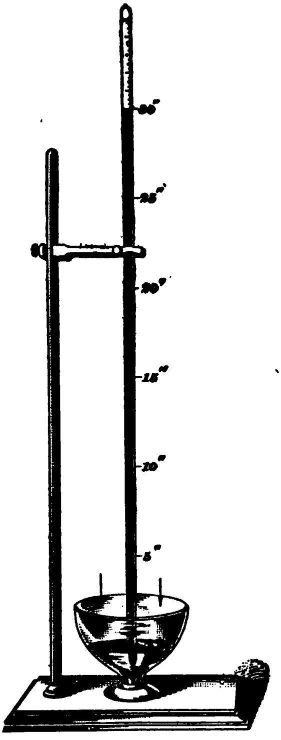


FIGURE 6. — SIMPLE BAROMETER.

Why must one end of the tube be closed? Where does the air press? Why does the mercury not reach the top of the tube? Scale is in inches.

Problem 4. How air pressure may be measured. — The amount of this pressure, which of course will also be the measure of the weight of the air over a certain space, may be found by repeating the experiment of Torricelli, a pupil of Galileo, made in 1643. This was the first measurement made of air pressure.

Experiment. — Fill with mercury a glass tube about three feet long and closed at one end. Closing the open end with the finger to prevent the escape of the mercury, invert the tube and place the open end below the surface of mercury in a dish. Now withdraw the finger and note the result (Figure 6). What keeps the mercury in the tube above the level of the mercury in the dish?

If the tube has a cross section of one square inch, the weight of the mercury held above the level of the mercury

in the dish will be about fifteen pounds. Therefore it may be stated that air exerts a pressure of about fifteen pounds per square inch.

The apparatus used in this experiment constitutes the essentials of a *mercury barometer* (Figure 7). Since weather changes are accompanied and frequently preceded by changes in air pressure, the practical value of the barometer may be understood.

Problem 5. Why water is not used in making barometers. — From the last experiment we learn that the pressure of the air will hold up a column of mercury about 30 inches in height. Would a longer or shorter column of a lighter liquid be held up? Explain. Evidently, therefore, in selecting a liquid to be used in a barometer, its weight must be considered.

Experiment. — Into each of two beaker glasses put respectively equal volumes of mercury and water. Lift the glasses. Which is the heavier? Put the beaker glasses containing the mercury and water on the opposite pans of a balance and by the use of weights find out how much heavier one substance is than the other. What is the result?

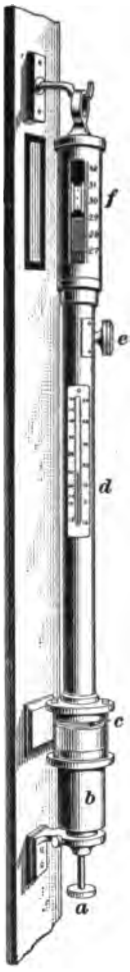


FIGURE 7. — MERCURIAL BAROMETER.

The height of the mercury column is measured in centimeters. *c*, surface of mercury upon which air is pressing. *a*, screw by which the mercury in the mercury cup is adjusted so that the surface (*c*) is at the zero point of the barometer tube. *d*, thermometer. *e*, screw for adjustment of a scale (vernier) by which the height of the mercury may be read more accurately. *f*, scale at top of mercury column.

If mercury is thirteen and one-half times heavier than water calculate the height of a column of water that may be held up by the pressure of the air. Such a barometer was constructed by Otto von Guericke, the inventor of the air pump.

FIGURE 8. — ANEROID BAROMETER.

The upper portion of the tube to the extent of about six feet was of glass. Floating on the top of the liquid, the inventor had introduced a small figure of a man which with the rising of the column in fair weather presented itself to view; but with the approach of foul weather retreated out of sight.

Problem 6. How an aviator knows how high he is. — If a barometer is carried up a mountain the mercury column drops about 0.1 of an inch for every 90 feet of elevation. Explain why this is so. Explain how an aviator is able to determine his height above the earth. Why is a mercury barometer unfitted for use in an airplane?

Can you suggest a method of making a barometer which will not have the objectional features of the mercury barometer? Reference to the experiment in Problem 3 may help you. Suppose some of the air is removed from a metallic box, having sides that go in or out as the pressure on it changes. What will happen to the sides when this box is carried up in an airplane? When it is carried back to the earth again?

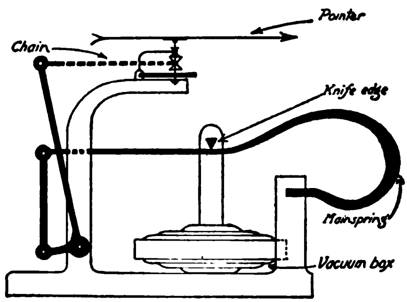


FIGURE 9. — DIAGRAM OF AN ANEROID BAROMETER.

The aneroid barometer is made according to this plan. In its simplest form it is a metal box from which a large part of the air has been removed. The cover will bend slightly with changes of pressure of the atmosphere. By a series of levers the extent of movements of the cover of the box is multiplied and represented by a pointer on a dial.

Problem 7. Why air pressure does not prevent us from lifting objects. — Calculate the weight of air resting on a book six by ten inches. You know, however, that the book can be lifted as though there were no weight on it. The following experiment may help you to understand how this can be.

Experiment. — Completely fill a glass with water and cover the top of it with a piece of cardboard, making certain that the cardboard is everywhere in close contact with the edge of the glass. Invert the glass (Figure 10). What happens? Why? Hold the glass in different positions. Result? Conclusion?

FIGURE 10.

Problem 8. Why a balloon or a dirigible remains in the air. — Why do you think that the explanation given for the airplane remaining in the air will not account for the buoyancy of a balloon? Since we have learned that air has weight we may compare the floating of objects in air with the floating of objects in water. You know from experience that objects like iron and stones, that are heavier than water, will sink while cork and wood, which are lighter than water, will float.

FIGURE 11. — FRENCH WAR BALLOON.
It is making an ascent at St. Nazaire, France.

The same is true of things in the air. Cork and wood and most things we know of are heavier than air and will not float in it. A balloon, however, is lighter than air and therefore will float in it. We know that air pressure is exerted in all directions. The air under the balloon, therefore, is pushing it upward and the air above it,

is pushing it downward. If the balloon weighs the same as air it will not be pushed either upward or downward. If,

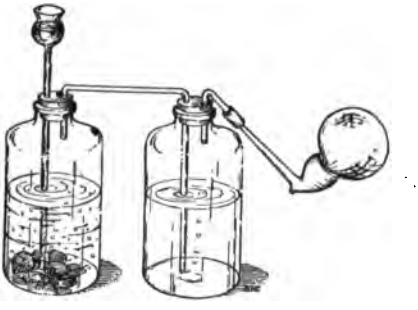


FIGURE 12.

however, the balloon weighs more than an equal volume of air, will the downward or upward pressure be greater? Explain. If the balloon weighs less than the air that it

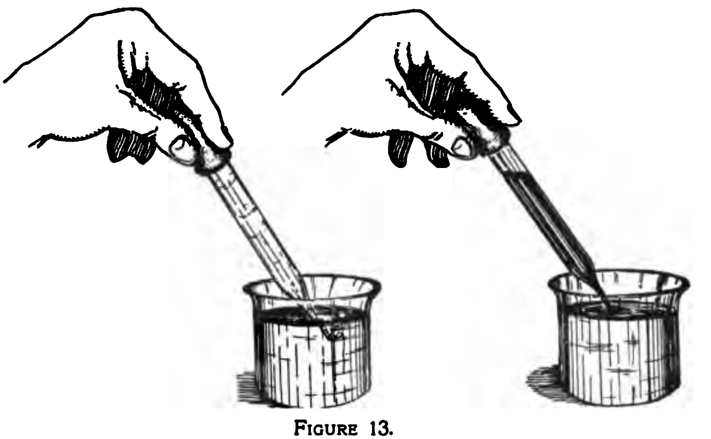


FIGURE 13.

displaces, which pressure will be the greater? Explain. Explain why a balloon does not continue to go up until it reaches the top of the atmosphere.

Balloons and dirigibles must be filled with a gas much lighter than air. Hydrogen gas, which is about $14\frac{1}{2}$ times lighter than air, has been the gas generally used. The use

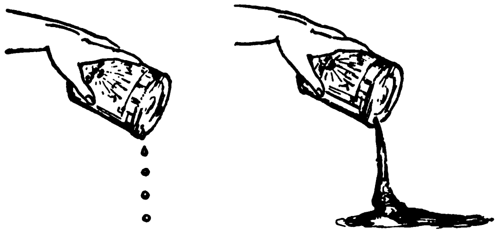


FIGURE 14.

Note that the can at the right has two holes in its top.

of hydrogen for filling balloons may be shown by making soap bubbles with it.

Experiment. — Make hydrogen by setting up the apparatus shown in Figure 12 and pouring hydrochloric acid through the tube with the enlarged top (thistle tube) over the pieces of zinc in the flask. By means of a rubber tube attach the stem of a clay pipe to the tube which carries the gas from the flask. Dip the bowl of the pipe into soapsuds. Shake off the bubbles into the air as they are formed and note their behavior. Touch a bubble with a match and observe what happens.

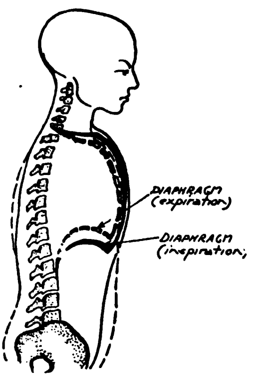


FIGURE 15. — RELATIVE SIZE OF CHEST CAVITY DURING INSPIRATION AND EXPIRATION.

A new gas (helium) which is found in considerable quantities mixed with the gas of some natural gas wells is now being used. It is somewhat heavier than hydrogen although much lighter than air. The great advantage of its use is that it will not burn, whereas hydrogen does.

EXERCISES

Explain the following:

(1) How ink may be drawn up into a medicine dropper such as is used in filling a fountain pen (Figure 13).

(2) How lemonade may be sucked through a straw.

(3) Why olive oil or any other liquid can readily be poured from a small opening in a can if there is another opening above the liquid, but will not flow evenly if this opening is closed (Figure 14).

(4) Why a fountain pen frequently leaks when it is nearly empty.

(5) Why the raising of the ribs and lowering of the diaphragm of the body causes air to flow into the lungs (Figure 15).

(6) Why two pieces of wet glass stick together.

(7) The action of non-skid automobile tires (Figure 16).

FIGURE 16. — NON-SKID AUTOMOBILE TIRE.

(8) The ability of basket ball players to keep from slipping on the smooth floor of a gymnasium (Figure 17).

FIGURE 17. — SOLE OF BASKET BALL SLIPPER.

(9) Action of the ordinary suction pump (Figure 18). How high will such a pump lift water?

(10) How air pressure may help in removing liquids from casks or large bottles (siphoning). (Figure 19.)

(11) Action of a vacuum cleaner. Why is its use advisable?

(12) Why one's hat is apt to be carried off as a swiftly moving train passes.

(13) The action of a self-filling fountain pen.

(14) Difficulty of drinking from a small-mouthed bottle.

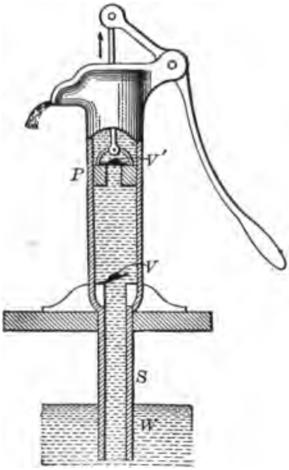


FIGURE 18. — SUCTION PUMP.

V, *V'* valves; *P*, piston; *S*, pump stem; *W*, water of well. What causes *V* to open as piston moves upward? What will be the position of valves as piston is pushed downwards?

(15) Sucking of blood by a mosquito.

(16) Noise caused by removing a thimble from a wet finger.

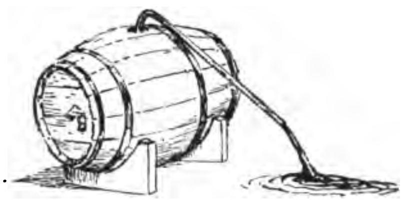


FIGURE 19. — SIPHONING LIQUID FROM A BARREL.

The tube fits loosely in the opening at the top of the barrel. Why is this necessary? Why cannot this barrel be completely emptied by the tube as it is? How can this tube be changed so that the barrel may be emptied with it?

(17) Difficulty of pouring a liquid through a funnel which fits tightly into the mouth of a jug or bottle. How may the liquid be made to flow rapidly?

(18) Why the body is not crushed by the pressure of the air.

Suggested Individual Projects[1]

1. Make a kite and demonstrate by diagrams how it is able to fly.
2. Make an air-glider and explain how it acts.
3. Make a model airplane that will fly and demonstrate its action to the class.
4. Construct a homemade mercury barometer and record for a period of time the changes in air pressure. At the same time make a record of the condition of the weather and determine if there seems to be any connection between changes in air pressure and the weather.
5. Construct and demonstrate a suction pump.
6. Demonstrate that air is heavier than hydrogen gas and is lighter than carbon dioxide gas.
7. Construct an apparatus to illustrate the expansion and contraction of the lungs in breathing.
8. Demonstrate the structure and action of a self-filling fountain pen.
9. Demonstrate the structure and action of a vacuum cleaner.
10. Construct a siphon and demonstrate its use. Discuss various applications that may be made of the siphon.

Reports

1. First successful attempts to cross the Atlantic Ocean in an airplane.
2. Early attempts to develop the airplane.
3. The use of the airplane in the Great War.
4. Commercial possibilities of the airplane.

References for Project I

1. Aircraft Today, Chas. Turner. J. B. Lippincott Co.
2. How to Fly, F. A. Collins. D. Appleton & Co.
3. The Air Men, F. A. Collins. Century Co.

[1] As explained in the Preface, not all the Individual Projects are to be required of every student. Some are for girls, some for boys; some for city pupils, some for country students; some are so simple that nearly anyone can perform them easily, while some, like Project 3 above, will appeal only to those who have a decided mechanical talent.

4. Boys' Book of Airships, H. Delacombe. Frederick A. Stokes Co.

5. How It Flies, Richard Ferris. Thomas Nelson & Sons.

6. The Story of the Airplane, C. Graham-White. Small, Maynard & Co.

7. Boys' Book of Model Airplanes, Vols. I and II, F. A. Collins. Century Co.

8. Aviation Book, Curtis. F. A. Stokes.

9. Harper's Book on Aircraft, Verrill. Harper & Bros.

10. Boys' Book of Inventions, Baker. Doubleday, Page & Co.

11. Flying Machines, etc., The American Boy's Handy Book, Beard. Charles Scribner's Sons.

12. War Kites, Field and Forest Handy Book, Beard. Charles Scribner's Sons.

13. Handicraft for Handy Boys, Hall. Lothrop, Lee & Shepard.

14. Historic Inventions, Holland. Geo. W. Jacobs Company.

15. Harper's Outdoor Book for Boys. Harper & Bros.

16. The Outdoor Handy Book, Beard. Charles Scribner's Sons.

17. Practical Things with Simple Tools, M. Goldsmith. Sully & Kleinteich.

18. Careers of Danger and Daring, Cleveland Moffet. Century Co. (Divers, Balloonists, Bridge Builders, etc.)

19. The Barometer as the Footrule of the Air. Taylor Instrument Co., Rochester, N. Y., 10 cents.

20. The Thermometer and Its Family Tree. Taylor Instrument Co., 10 cents.

21. The Story of Great Inventions. Harper & Bros.

22. Modern Triumphs, E. M. Tappan, Editor. Houghton Mifflin Co.

23. Harper's Machinery Book for Boys. Harper & Bros.

PROJECT II

HOW WE USE COMPRESSED AIR

THE fact that we not only make use of air pressure but also of compressed air is familiar to us all. Automobiles weighing several thousands of pounds are held up by compressed air. The construction of bridge foundations and tunnels under the beds of rivers is made possible by it. Moving trains weighing hundreds of tons may be quickly brought to a stop by the air brake. Drills, riveting machines, and many other appliances are operated by compressed air. How such a substance as air can do all these things opens up for us many problems.

Problem 1. How air pressure is used in building foundations and subways. — What is an air bubble? Can air and water occupy the same space at the same time?

Experiment. — To find out if air and water can occupy the same space at the same time, push down into a vessel of water an inverted drinking glass (Figure 20). What is the result? It is evident that the pressure of the air within the glass is sufficient to prevent the entrance of the water into the glass.

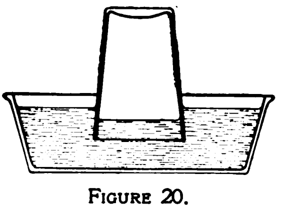


FIGURE 20.

This pressure is equal to the weight of the column of water above the level of the water which is inside of the glass plus the ordinary atmospheric pressure (how much?) on the surface of the water. As the glass is pushed downward will

any change occur in the amount of pressure exerted by the contained air? At what depth in the water will the air exert a pressure equal to two atmospheres? At this point the volume of the air will be one half of its original volume, illustrating a law of every true gas, that the volume varies

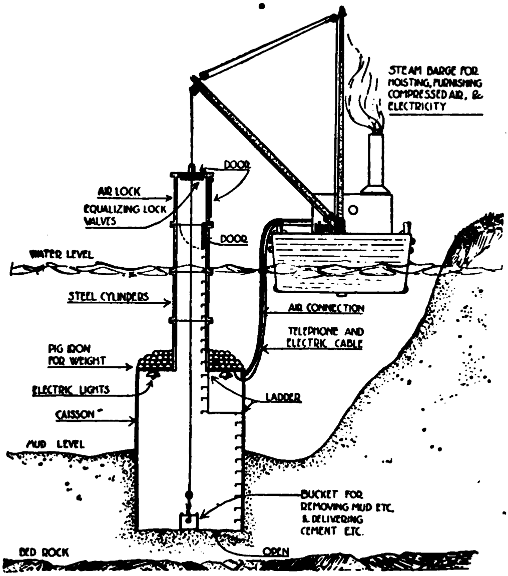


FIGURE 21. — CAISSON.

If the pressure of the air in the caisson is about 30 pounds per square inch, how far from the surface of the water is the bottom of the excavation? What would happen if the doors at the top should be left open? Why?

inversely as the pressure exerted upon it. This law is known as *Boyle's law.*

Caissons used in building foundations under water are large metal cylinders open at the bottom, into which air is pumped until it exerts sufficient pressure to prevent the entrance of water (Figure 21). Air under pressure was used

to keep out the water during the construction of the tunnels under the East and North rivers at New York City.

Great care must be taken by men passing from the compressed air chambers to the outer air. If this is done too quickly, gases which are dissolved in the blood form small bubbles which prevent the blood from passing through capillaries (very small blood vessels), causing an acute disease, the "bends." To prevent this, a man instead of passing directly into the outer air goes through several rooms of graduated pressures, remaining in each room a sufficient length of time to permit the body to accommodate itself to the changed pressure.

Problem 2. How compressed air is used in automobile tires. — We all know that bicycle tires and most automobile tires are filled with air. At first thought it seems strange that a substance like air can hold up the great weight of a heavy automobile. Naturally we ask how this air is different from the air around us.

What happens if a nail punctures the tire? Sometimes when the outer covering of the tire becomes badly worn a "blow-out" occurs with a noise like an explosion, tearing a hole in the tire. What does this indicate to you concerning the condition of the air within the tire?

It is evident that the compressed air in the tire is able to hold up the weight of the automobile amounting to several thousand pounds, just as the compressed air in the diving bell resists the pressure of the water.

If you have ever ridden in a solid-tired automobile and then in one having pneumatic or air-filled tires, you have noticed that in the latter case the jars caused by the roughness of the road were not felt as much. This

observation shows that the compressed air in the tire acts like a spring. The following simple experiment will show this effect of compressed air.

Experiment. — Bounce together on the floor a new, perfect tennis ball and a tennis ball in which a small hole has been made by a pin or nail. Result? In the same way compare the bouncing of a basket ball which is just sufficiently filled with air to cause it to keep its shape with the bouncing of a similar ball into which a large amount of air has been pumped.

From the observations you have made you will conclude that the compressed air in the automobile tire is able to support a great weight and gives springiness (elasticity) to the tire. Many tire-filling compounds have been tried but none has been successful because nothing has been found that will give the springiness possessed by compressed air.

It is evident that in the construction of an automobile tire, first, the tire must be air-tight to prevent the escape of the air and, second, it must be of sufficient strength to resist the pressure of the imprisoned air. An examination of an automobile tire will show how these two requirements are met. The inner tube made of elastic rubber is air-tight. The air is pumped in through a metal tube in which is a valve that will allow air to be pushed in but prevents its escape.

The outer tire or shoe is not necessarily air-tight but provides the strength to resist the outward pressure of the confined air. It is very strongly made of a combination of cotton fabric or cord and rubber. In bicycle tires where the weight supported is not so great, frequently only one tube is used. What two properties must this tube possess?

Air is forced into the tire by an air pump.

Problem 3. How the tire pump works. — If you have ever pumped up an automobile tire, did you find it more

difficult to work the pump when the tire was nearly empty or when it was nearly filled? In the tire pump which you used, was the push or the pull upon the handle the harder? Does a tire pump ever "get out-of-fix" or fail to work?

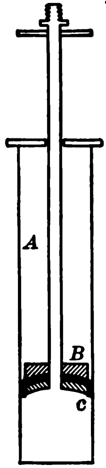


FIGURE 22. — BICYCLE PUMP.

Keeping these points in mind let us examine the diagram of an air pump (Figure 22). As the handle is pulled out, what happens to the air? Why? As the handle is pushed down, what happens to the air? Why does it not go out through the same place through which it came in? Why is it more difficult to push the handle down than to pull it up? Why is it more difficult to push the handle down as you continue to pump air into the tire?

The tire pump is a very simple air compressor, but air compressors for air brakes, pneumatic drills, sand blasts, and for pumping air into tunnels where work is done under compressed air are built on the same principle.

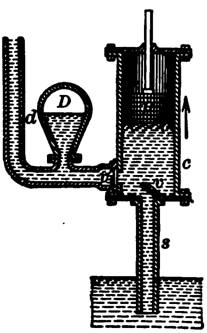


FIGURE 23. — FORCE PUMP.

p, piston; *c*, cylinder; *v*, valve; *D*, dome containing air; *d*, delivery pipe; *s*, pump stock.

Suppose the valve through which the air enters the pump should be reversed, what would happen should the nozzle be attached to a basket ball and the pump used? This is the principle of the exhaust air pump, by which air is pumped out of a closed vessel. Do you think that all of the air could be removed from a vessel with such a pump? In answering this, keep in mind that however little air

is in a space, it will be distributed equally, filling all the space.

Problem 4. How a force pump sends a steady stream of water. — The tire pump is really an air force pump; a water force pump could be made on the same plan. Would

FIGURE 24. — COMPRESSED AIR DRILLS.
Use of compressed air drills in excavating a tunnel through solid rock.

such a water force pump send a steady stream of water? Such pumps are valuable in pumping water to a tank on the top of a house or into a standpipe. Why cannot an ordinary pump be used for this purpose?

Some force pumps can send a steady stream of water. It will be noticed that pumps of this kind have connected with

them an iron dome. An examination of the accompanying diagram will help us to understand how this is possible (Figure 23).

Explain what happens when the piston (*p*) is pulled up. When it is pushed down, what two courses will the water take? What will happen to the air that is in the iron dome? What will this compressed air do to the water when the piston starts upward and the water is no longer being forced

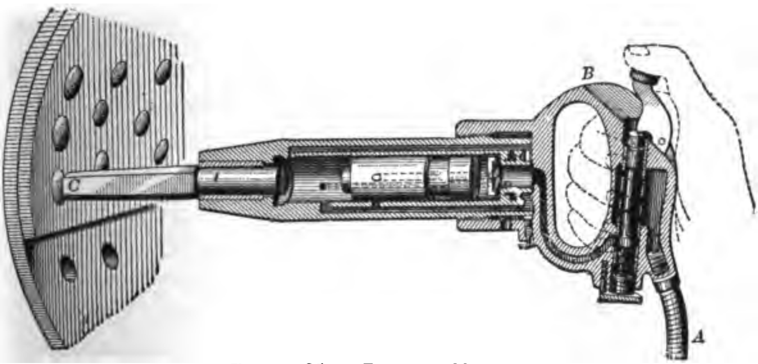


FIGURE 25. — RIVETING HAMMER.

A, air pipe; *B*, trigger for controlling the air; *C*, the hammer.

into the dome? What kind of a stream will such a pump send out? The power of compressed air to throw a stream of water is illustrated by the following experiment.

Experiment. — Half fill a flask with water. Stopper it with a one-hole stopper through which passes a tube extending down below the surface of the water. Blow through the tube. What effect will this have upon the air within the flask? After the air has been considerably compressed, stop blowing into the tube and observe what happens.

Some other important uses of compressed air are: — Pneumatic tubes for the transmission of mail, and of cash

and parcels in stores; air brakes; pneumatic drills and riveters; and the sand blast used in cleaning the fronts of stone buildings. Can you suggest any other applications?

Suggested Individual Projects

1. Construct a pump that will send a steady stream of water.
2. Demonstrate the working of air brakes.
3. Demonstrate the structure and the action of pneumatic drills.
4. Demonstrate the structure and the method of working of the sand blast used in cleaning the outside of brick and stone buildings

Report

Use of compressed air in building bridge foundations and in the construction of subways.

PROJECT III

VENTILATION

WHAT do you understand by *ventilation?* We hear a great deal about the importance of ventilation, so that we naturally ask ourselves, why ventilation is so necessary and how rooms may be ventilated.

Problem 1. Why rooms should be ventilated. — Think of how you have felt in rooms that were not ventilated and in rooms that were ventilated. Did the fact that the room was empty or full of people seem to make any difference? What effect do people have on the air of the room? Your first answer to this will be that even if pure air is breathed in, impure or bad air is being breathed out. What, then, will be one reason for the ventilation of a room?

Another effect of a crowd of people on the air of a room is noticed when you step from the fresh air into a poorly ventilated room full of people. Unpleasant odors are noticed. These are given off by the mouths, bodies, and clothing of the persons in the room. Experiments have shown that these odors are not only annoying but have a bad effect on the appetite. What, therefore, is a second reason for the ventilation of rooms in which there are many people?

Another reason for ventilation may be made clear by an experience common to us all. How do you feel on a hot sultry day in summer? Do you feel different when a breeze begins to blow? What is the effect of riding in

an open trolley car or in an automobile on such a summer day?

The following experiment may help us to understand the reason for this change in feeling.

Experiment. — Put a drop of ether on the back of the hand. What happens to the ether? How does the spot, where the ether was, feel?

Put a drop of water on the other hand. After it has been there a few moments, fan the hand. Do you notice any difference in temperature? The changing of the ether and water into a vapor or gas that is invisible is called *evaporation*. What do you conclude is the effect of evaporation upon temperature?

Heat is being continually made in the body. How do you suppose the body loses most of its extra heat in warm rooms and in summer time?

Evaporation of water goes on much more slowly if there is already a large amount of water vapor in the air. This fact is made clear to you by the rapidity of the drying of clothes on a damp day and on a dry day. In which case does the drying go on more rapidly?

Experiment. — Wet two small pieces of cloth; hang one in a dry battery jar and the other in a battery jar in which there is a small amount of water. Which piece of cloth dries the sooner? Conclusion?

It is estimated that each person gives off from his mouth and skin about three pints of water daily and about as much heat as is produced by a candle flame. Of course, if exercise is being carried on, both more moisture and more heat are given off. What, therefore, will be the condition of a poorly ventilated room in which there are a number of persons?

It is an accepted fact that the dullness and drowsiness felt in such a room are due chiefly to the heat and moisture. Experiments have shown that men do 15 per cent less work at a temperature of 75 degrees F. and 37 per cent less work

at 86 degrees F. than at 68 degrees F. In warm rooms the blood comes to the surface of the body. Why? What effect will this have upon the amount of blood that goes to the brain? What will be the result? In the same way, the blood vessels in the nostrils become congested, making an ideal condition for the growth of germs. As a result, people who live in overheated rooms usually have colds. The proper temperature for a room is 68 to 70 degrees F.

Although a poorly ventilated room containing many people is likely to have too much moisture in the air, there is danger in the winter of having too little moisture in the air; this is especially true in apartments occupied by only a few people. It is advisable under these circumstances to keep on the radiator or stove a basin of water which will supply moisture to the air by its evaporation. Hot air furnaces have a special water basin which should be kept filled if the occupants of the house are to enjoy the maximum of comfort and well-being.

FIGURE 26. — ELECTRIC FAN.

Briefly summarize the reasons for ventilating a room.

Problem 2. How air in a room may be set in motion. — One method of keeping the air of a room in motion is by the use of fans (Figure 26). Explain why, in summer, one feels

so very much better in an office, room, or subway car in which an electric fan is in motion. Recall how quickly one feels the change when the fan is shut off. Why is ventilation of a room entirely by an electric fan not a perfect method? What is not provided for by such ventilation?

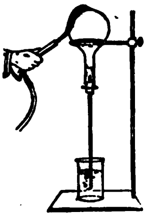


Figure 27.

We know, however, that most ventilating systems do not depend on fans. The question then is, how may a circulation of the air be caused, when fans are not used. The following experiments may help us to answer this question.

Experiment. — Put a lighted candle in the bottom of an uncovered battery jar. Light a stick of Chinese punk or incense and hold it near the top of the jar. What happens? What do you think may be the cause of this?

Experiment. — To find out the effect of heat on the weight of air, place a lighted Bunsen burner near one of the scale pans of a sensitive balance. Result? Conclusion? The reason for this is made clear by the following experiment.

Experiment. — To find out how heating air makes it lighter, pass a glass tube through the stopper of a flask. Take care that the stopper is air-tight. Invert the flask, placing the outer end of the glass tube under water. Gently heat the flask (Figure 27). Result? Conclusion?

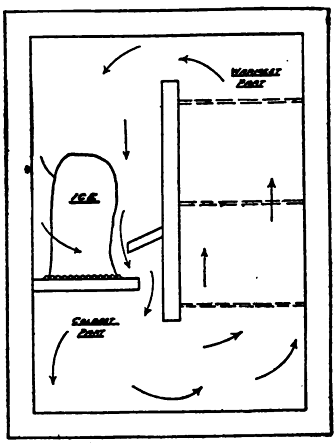


Figure 28. — Currents of Air in a Refrigerator.

The currents of air caused by heat are called *convection currents*. These currents of air are well illustrated by movements of air in a refrigerator (Figure 28).

Problem 3. How convection currents may be used in ventilating a room. — Windows are very frequently depended upon for ventilation.

Experiment. — To find out the best arrangement of windows for good ventilation of a room, take a wooden soap box or a starch box. Across the front of the box place a piece of glass so that it may act as a sliding door. In each end of the box bore four holes so arranged as to represent the upper and lower parts of windows. Provide corks for these openings. Place inside of the box one or more candles. Light the candles. Allow all the lower holes to remain open. Note the result. Try various combinations. What is your conclusion as to the best way to ventilate a room by means of windows?

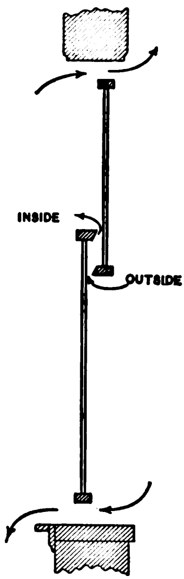


FIGURE 29.—VENTILATION BY WINDOW.

Window open at both top and bottom.

If the air outside is cooler than the air inside the room, and the window is open at both top and bottom, where does the air enter and where does it leave (Figure 29)? Explain.

A draft or a direct current of air striking against the body is apt to induce a cold since that portion of the body is cooled so completely that the blood coming there is forced into some other part, causing a congestion which affords a favorable condition for the growth of bacteria or germs that cause colds.

With a window open at the top and bottom, would the greater danger of draft be from the top? Suggest means of protecting persons from a draft in a room ventilated in this way.

Explain how a stove or fireplace will help in the ventilation

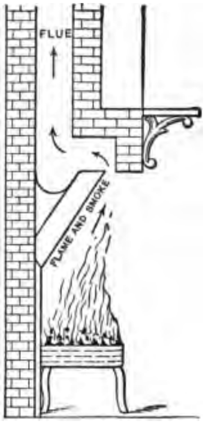


FIGURE 30. — FIREPLACE.
What causes the air to go up the flue?

of a room (Figure 30). Make a diagram of a room containing a fireplace and indicate by arrows the direction of the air in the room.

How are your rooms at home ventilated in summer? In winter? Make diagrams of the summer and winter ventilation of one room.

Modern office buildings, and sometimes schools, are heated and ventilated by air being forced into them by fans through large pipes. If the air comes in heated, ought the inlet to be at the top or bottom of the room? Where ought the outlet to be?

Experiments and observations have shown that the health is much better if sleeping rooms are well ventilated and kept at a relatively low temperature, provided that the body is not in a draft and is properly protected to prevent its becoming chilled.

Suggested Individual Projects

1. Carry out a series of experiments to show the direction of air currents in a room. Show results in a diagrammatic drawing of the room. Do this for different rooms of your house.

2. Carry out a plan to prevent a draft in a room ventilated by windows.

PROJECT IV

WINDS

SINCE winds are movements of air, you would naturally suspect that they may be caused in the same way as the air currents of ventilation. In considering the cause of winds you will at once think of different kinds of winds, such as sea breezes, gentle breezes that seem to come from any direction, violent gales, trade winds, hurricanes and tornadoes. Does it seem probable that all these winds are caused by the unequal heating of the air?

Problem 1. How sea breezes are caused. — Anyone living within a few miles of the sea coast is familiar with the breeze that springs up on hot days in summer. Since this wind occurs only on hot days and dies down toward evening, being replaced frequently during the night by a breeze from the land to the ocean, you will suspect that in some way it is concerned with heat.

If this wind is caused in the same way that air currents of ventilation are produced, there must be an unequal heating of the land and water. Do you think that the ocean and the land receive different amounts of heat from the sun? The problem to be solved, therefore, is, how the unequal heating can be accounted for.

Experiment. — Put into different drinking glasses or beaker glasses equal quantities of water and earth. Put them into an oven for about twenty minutes. On removal put into each beaker glass a thermometer.

Note the temperature when first removed from the oven and at intervals of ten or fifteen minutes. Result? Conclusion?

Explain now the cause of sea breezes.

The seasonal or monsoon winds of India are accounted for in a similar manner. During the summer the land becomes highly heated and winds blow from the Indian ocean to

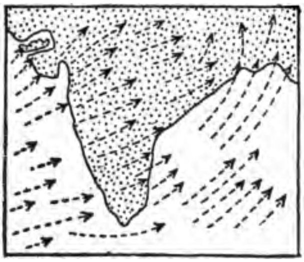


FIGURE 31. — SUMMER MONSOON.

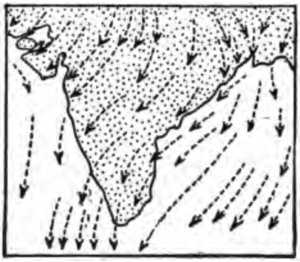


FIGURE 32. — WINTER MONSOON.

the land, while in winter the water is warmer than the land and the direction of the wind is reversed.

Considering the fact that land becomes warmed more rapidly and cools more rapidly than water, explain the following:

1. Why New York City has a later spring than places in Ohio and Indiana which are no farther north or south.

2. Why the region along Lake Ontario is better for raising fruit than places much farther south.

On the diagram representing the world's winds note the direction of the trade winds. Why do they blow toward the equator? The fact that they blow from the southeast and northeast rather than directly from the north and south is due to the rotation of the earth. In the northern hemisphere the winds are deflected to the right and in the southern, to the left.

Problem 2. Why our winds vary in direction and velocity. — Note the direction of the winds in your locality for a few days. Do they always come from the same direction? Do they always seem to come from a cooler to a warmer place? Do you think that they are caused in the same way as sea breezes?

FIGURE 33. — THE WORLD'S WINDS.

Reference again to the diagram of world's winds may help us. In what general direction are the winds of the part of the world in which we live? These winds are called the prevailing westerlies.

FIGURE 34. — PROGRESS OF A STORM CENTER.

Note the rate of speed of this storm center.

Because of inequalities of heating and irregularities of surface, *low pressure areas* develop in this general current (the prevailing westerlies). As the air rushes in toward a low pressure area a whirlpool is formed such as you may see as the water is drained from your bath tub, or in the dust

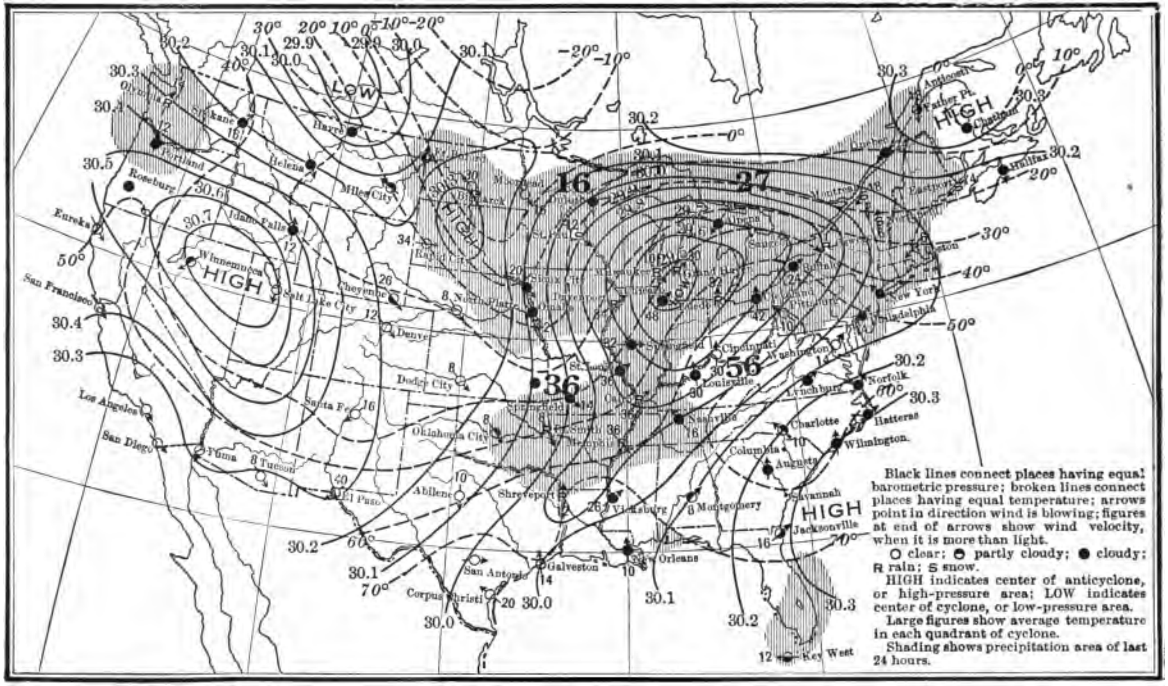


FIGURE 35. — WEATHER MAP.

Note the direction of the wind in each part of the cyclone.

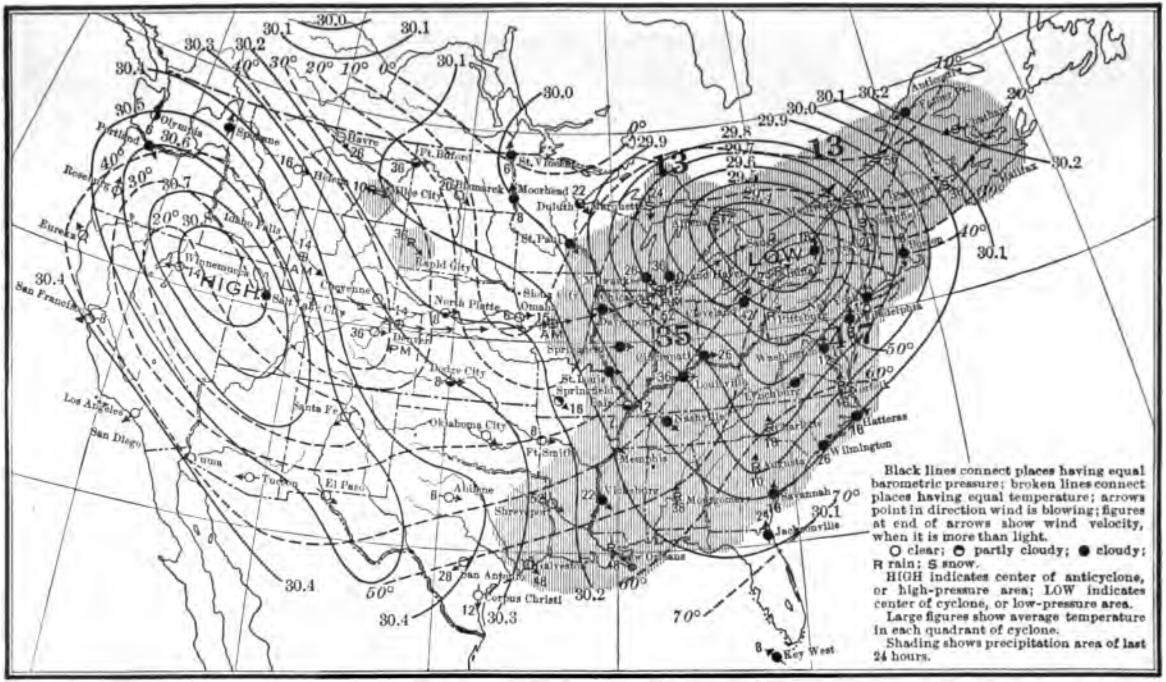


FIGURE 36.—WEATHER MAP OF THE FOLLOWING DAY.

How has the position of the low changed since the preceding day? Where do you think the low will be to-morrow? What change in temperature will you expect in the vicinity of New York? Why?

whirls which occur in the road in summer. The low pressure which started the dust whirl is formed by the excessive heating of a small area of the road.

These low pressure areas which develop in the prevailing westerlies travel with the westerlies in a general direction from west to east (Figures 34 and 37). The air for hundreds of miles passes in toward a low pressure area, not

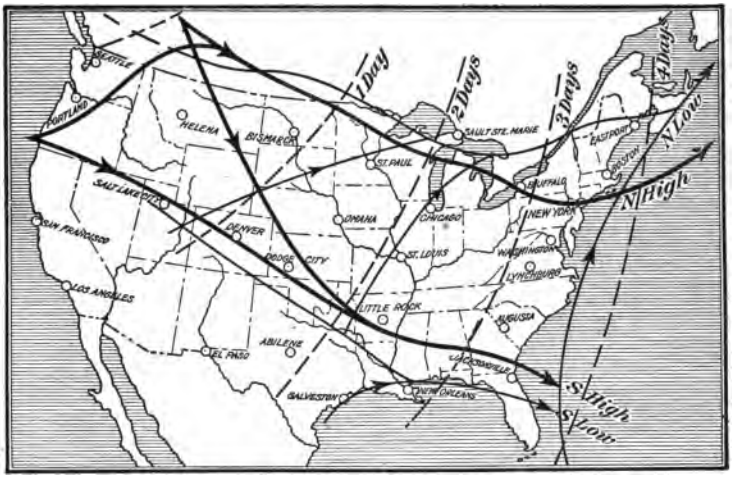


FIGURE 37. — USUAL PATHS OF "HIGHS" AND "LOWS."

directly but in a spiral, just as water does when drained from a bath tub. These great whirls of air, which are continually passing across the country, are called *cyclones;* and most of our winds are portions of these. The cyclones, of course, are separated by areas of high pressure (Figures 35 and 36).

Directly in the center of a low pressure area, in what direction do the currents of air flow? What is the direction of these currents in the center of a high pressure area?

Which is warmer, an area of low pressure or an area of high pressure? Low pressure areas are cloudy and rainy. High pressure areas are clear.

Tornadoes are violent wind storms, and are sometimes wrongly called cyclones. They are usually not more than 40 to 500 yards in width. In tornadoes the air is rushing spirally upward at a rate of 100 to 400 miles per hour. Directly in the center of the tornado there is a very much

Photograph by F. C. ...

FIGURE 38. — TORNADO.

This tornado was seen near Isabel, South Dakota, June 25, 1914.

lessened air pressure. The condensation of moisture within this area of lessened pressure and the presence of dirt carried up by the air cause the funnel shaped cloud which is characteristic of this kind of storm (Figure 38).

But a cyclone is an entirely different kind of storm. Compare a tornado and a cyclone as to size. Tornadoes usually occur in the southeastern part of a cyclone and move toward the northeast, which is the direction of the

prevailing wind in that part of a cyclone. They travel at the rate of 20 to 50 miles an hour.

Tornadoes are very destructive, frequently destroying everything in their paths (Figure 39). Trees may be completely demolished; large stones and even locomotives have been known to be carried a considerable distance; straws have been driven into wood as though they were

FIGURE 39.—RESULTS OF A SEVERE WINDSTORM.

nails, and many other astounding results have been known to occur. Frequently the walls of buildings near which the center of the storm passes fall outward as though from an explosion. Explain this. Waterspouts are whirlwinds over the ocean.

Problem 3. What are hurricanes? — *Hurricanes* are similar to cyclones but are usually of less extent and more violent. They form over the ocean. The ones that affect us originate near the West Indies and move toward the

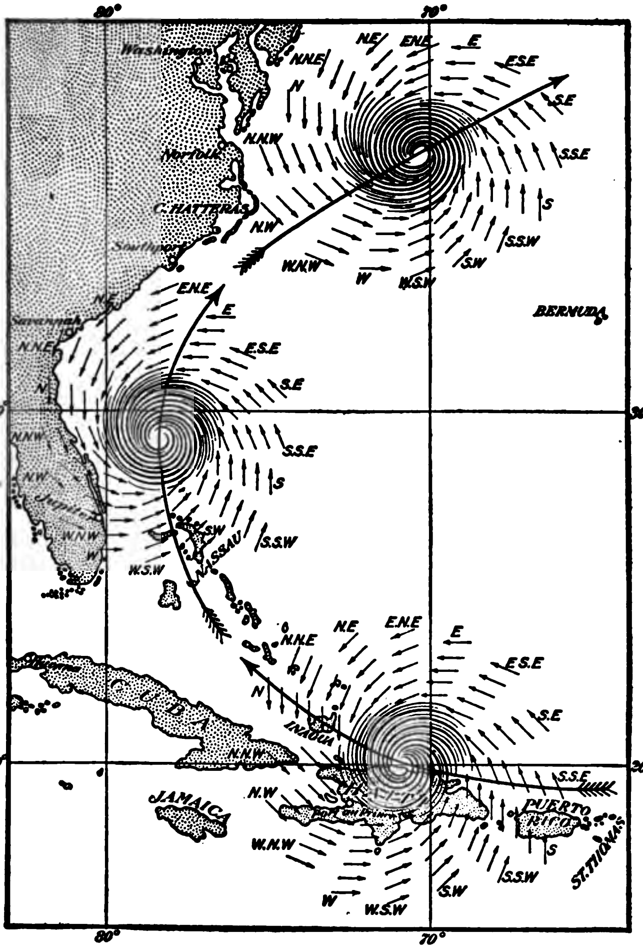


FIGURE 40. — PATH OF A HURRICANE.

northwest until the coast of the United States is reached. They then move toward the north and northeast, parallel with the coast, finally passing eastward out into the

Atlantic Ocean (Figure 40). Occasionally, one of these hurricanes passes into the Gulf of Mexico. Galveston, Texas, was nearly destroyed in 1900 by the waves produced by such a hurricane. Similar storms in the Pacific and Indian oceans are called *typhoons*.

Thunderstorms frequently develop at the close of a hot, sultry day. They are caused by the rising of hot, moist

Photograph by McAdie.

FIGURE 41.—CUMULUS CLOUDS.

air. The moisture of the air condenses into dome-shaped, white clouds known as *cumulus* clouds (Figure 41). The downpour of water is accompanied or preceded by a settling downward of the cooler air which pushes out from all sides of the storm area, forming the strong wind of the approaching thunderstorm. After the thunderstorm has passed, the temperature is usually cooler, largely because of this settling of the cooler air from above.

Thunderstorms usually occur in the southeastern portion of a low pressure area, and move in an easterly direction at the rate of 20 to 50 miles an hour. The storm is preceded as it travels by a sheet of clouds advancing at a rather high elevation. As the storm draws near, there appears the black mass of the main storm cloud. Soon the dense curtain of rain may be seen pouring from its base (Figure

FIGURE 42. — THUNDERSTORM.

Photographed by Lieutenant W. F. Reed, Jr., U. S. N. R. F., near Pensacola, Florida, August, 26, 1918. (Published by permission of the Navy Department.)

42). Along the front of the rain there is often a low cloud, ragged and torn by the wind.

A short time after the rain ceases, sometimes even before, the sky may begin to clear; and the sun shining on the departing rain curtain gives us one of the most beautiful and wonderful spectacles of Nature, the rainbow. Then the storm cloud, illumined by the sun, may be seen passing eastward.

Problem 4. How the weather bureau is able to predict the weather. — Examine weather maps. Note the direction of winds, temperature, raininess or cloudiness, and low and high pressure areas. Suggest a basis for the weather predictions issued by the U. S. Weather Bureau.

Explain how a barometer enables one to forecast the weather for a short time in advance.

What two factors are important in determining the velocity of a wind at any one point?

Explain how a hot wave may be caused by a cyclone. Explain how a blizzard or "norther" may be caused by a cyclone. Suggest the relation between a cold wave and a high pressure area.

The United States Weather Bureau has nearly 200 observation stations throughout the United States and Canada, at which simultaneous records of barometric pressure, temperature, direction and velocity of the wind, the rain or snowfall and cloudiness, are made. These observations are telegraphed to Washington and from there the collected information is sent to the various stations where weather maps showing the weather conditions in all parts of the country are made. The forecasters study these maps and are able to forecast the probable weather conditions for the next 24 or 48 hours (Figures 35 and 36).

By means of telegraph, telephone, wireless, and mail or by means of flags or steam whistles the daily forecasts reach every part of the country in a surprisingly short time.

Special warnings of frost and the approach of a cold wave are sent to farming, gardening, and fruit districts and to railroads and to shippers of vegetables and livestock. Warnings of gales along coasts and on the Great Lakes are sent to shipping offices and to vessels.

Suggested Individual Topics

1. Keep a daily record of temperature, air pressure, direction, and approximate velocity of the wind, cloudiness, and rain- or snowfall. In connection with these observations study the maps of the United States Weather Bureau.

2. Make a toy windmill and use it in running a simple machine.

Reports

1. The work of the United States Weather Bureau.

2. An account of the hurricane that caused so much damage to Galveston, Texas.

3. An account of a tornado.

References for Project IV

1. Weather and Weather Instruments, P. R. Jameson. Taylor Instrument Company, Rochester, N. Y., 50 cents.

2. Practical Hints for Amateur Weather Forecasters, P. R. Jameson. Taylor Instrument Company, 10 cents.

3. Instructions for Volunteer Observers. U. S. Weather Bureau, Washington.

4. Practical Exercises in Elementary Meteorology, Ward. Ginn & Co.

6. About the Weather, Mark W. Harrington. D. Appleton & Co.

7. The Weather and Climate of Chicago, Cox and Armington. University of Chicago Press.

8. The Wonder Book of the Atmosphere, E. J. Houston. Frederick A. Stokes Co.

9. Our Own Weather, Martin. Harper & Bros.

10. Reading the Weather, T. M. Longstreth. Outing Publishing Co.

PROJECT V

HOW WE HEAR

THINK a moment of what you would miss and how you would be handicapped if you were unable to hear. Make a list of ten examples in which inability to hear would affect you.

In considering how we hear, there are several things which are at once evident; first, there is always a sound of some kind; second, the sound may be reproduced or heard at some distance from the place where it was originally produced; third, we have a special organ, the ear, which receives the sound. In working out this project, therefore, it will be necessary to know just what sound is, how sound may travel and be reproduced and how the human ear is fitted to receive sounds.

Problem 1. What sound is. — Think of the different ways in which sound is produced. How is a drum made to give out sound? What is the effect of putting the hand on the head of the drum while it is sounding? A violin or banjo gives out sound when a string is pulled to one side and then released. If the string is looked at carefully, it will be seen to be vibrating. What happens the moment you stop these vibrations by touching the string?

Experiment. — Touch the surface of water in a glass with the tips of a tuning fork which is sounding (Figure 43). Result? Conclusion?

An examination of all bodies giving out sound will lead us to the conclusion that sound always originates as a vi-

bration. The vibrating bodies cause air waves very much as the vibrating tuning fork produced waves in the water in the glass.

Experiment. — Blow diagonally into a small bottle or test tube. Use tubes and bottles of various sizes. Result? In this experiment air waves are produced directly.

It is in this way that sound is produced in such instruments as the organ, flute, cornet, and trombone. The sound here is produced by the vibration of columns of air.

In what three ways do sounds differ? Naturally we wonder, what are the causes of these differences.

Experiment. — Compare the sound (note) given by a violin or other stringed instrument when the strings are stretched very tightly and when the strings are stretched less tightly. By holding the finger on the string permit only a portion of it to vibrate. Result? Set into vibration one of the very slender strings of a violin or guitar and one of the thicker ones. Even though they are of the same length and of the same tension or tightness, what is the result?

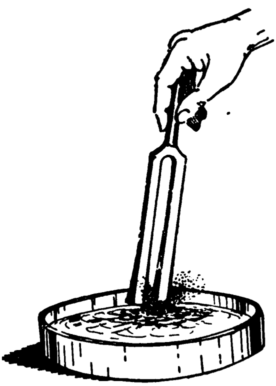


FIGURE 43.

A careful examination will show that in every case where the tone or pitch was high, the vibrations were more rapid than when a lower pitch was produced. You will also recall that blowing into very small bottles gave a much higher pitch than blowing into larger ones. This was because the air vibrations produced in the smaller bottles were more rapid.

If you look at the arrangement of strings of a piano, you will find that they are not all of the same length; the ones

which give out the low tones being long and thick, and those which produce the high tones, short and thin.

The human voice illustrates this very well. Children have high-pitched voices, but boys' voices usually become deeper or lower-pitched when they are about fourteen years old. This is because the voice box, or "Adam's apple," of the boy becomes considerably larger at this time, and the vocal cords become longer and larger, and therefore vibrate more slowly, producing a lower tone. The voice box of a girl does not usually grow much larger as she gets older, and consequently the voice of a woman remains high-pitched.

FIGURE 44. — ONE OF THE EARLIEST TALKING MACHINES.

If you are beating a drum and wish to make a louder sound, what do you do? If some one is sleeping and you do not wish to disturb him, how do you walk across the floor?

The loudness of sound is caused by the width of the vibration. Compare the sound given by the string of a violin when it is set into gentle vibrations with the sound produced when the vibrations are greater. It will be noticed that the tone or pitch remains the same, but that there is a great difference in loudness or volume.

The quality of the sound is due largely to secondary vi- ons (overtones) which vary with the character of the

sounding bodies. Hence, sounds of the same pitch and loudness produced by piano, violin, guitar, or organ, have distinctive qualities. This is, of course, the main reason for having many kinds of instruments in an orchestra.

Briefly summarize your conclusions as to what sound is and the cause of differences in pitch, loudness, and quality of sounds.

FIGURE 45. — PHONOGRAPH.

Note the sound box, to which is attached a needle which runs in the groove of the record.

Problem 2. How a phonograph reproduces sound. — To understand how the voice of Caruso, the music of the violin of Mischa Elman or of a wonderful church choir may be reproduced in our own home by the phonograph, it will be necessary to consider how the record is made.

The essential part of a phonograph is the sound box with

its diaphragm which is similar to the head of a drum (Figure 45). To the center of the diaphragm is attached a rod which transmits to a needle any movement of the drum head or diaphragm. Every vibration of the vocal cords of the singer or of the strings of the violin produces in some

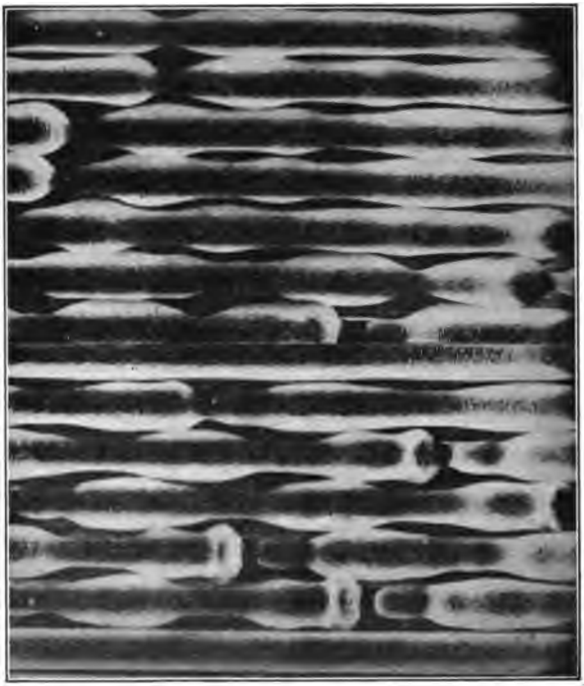


FIGURE 46. — MICRO-PHOTOGRAPH OF PORTION OF A RECORD.

way a similar vibration of the diaphragm which transmits the vibration to the needle which in turn leaves a record on a revolving wax plate upon which it rests (Figure 46). Copies of the wax plates made of hard material are the records which we buy (Figure 47). How the vibrations

of the diaphragm, located many feet from the source of the sound, are caused is a problem to be solved. Evidently there is nothing but air to carry the vibrations.

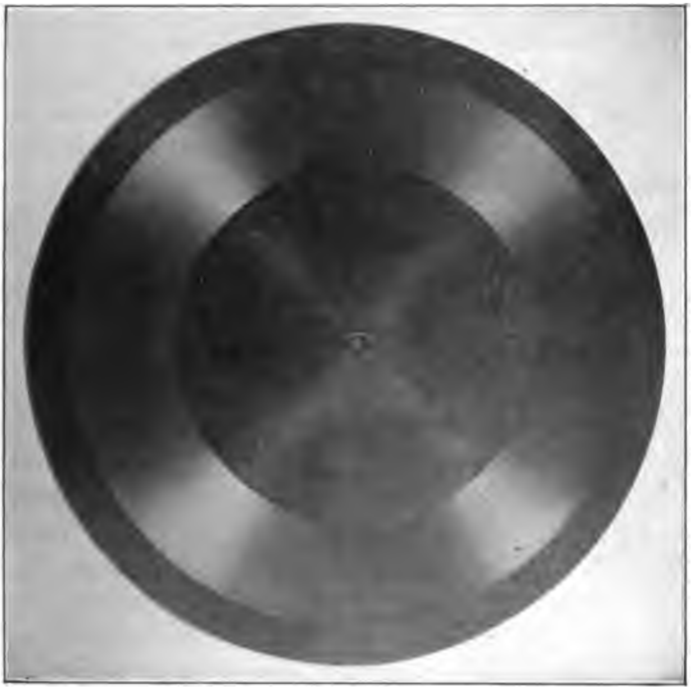


FIGURE 47. — PHONOGRAPH RECORD.
An original wax impression of a phonograph record.

Experiment: Does air conduct sound? — Through the stopper of a wide-mouthed bottle pass two wires connected with several dry cells and a key for closing the circuit. (Care should be taken to make the stopper air-tight.) Attach the ends of the wires to the binding posts of an electric bell. Place the bell in the bottle, insert the cork, and close the circuit. Can you hear the ringing of the bell? Now put a small amount of water in the bottle and heat it until the steam drives

out the air, put the stopper into the bottle and, after the bottle has cooled, again close the circuit. Do you hear the ringing as before? Allow air to enter the bottle gradually. As it does so, do you notice any difference in the sound of the bell? Conclusion?

As the finished record revolves under the needle, all the movements of the original needle are reproduced and corresponding vibrations are set up in the diaphragm of the sound box. These in turn cause air waves like the original ones and we may enjoy wonderful musical treats which in most cases would otherwise be unattainable.

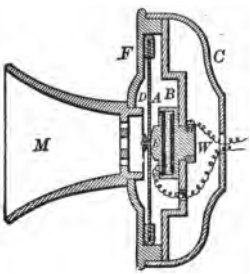


FIGURE 48. — TELEPHONE TRANSMITTER.

M, mouthpiece; *F* and *C*, front and back of metal case; *D*, aluminum diaphragm, held around its edge by a soft rubber ring; *A* and *B*, parallel carbon plates, separated by carbon granules.

In the telephone the air waves produced by the voice cause vibrations of the diaphragm in the telephone transmitter (Figure 48). By means of an electro-magnet, concerning which we shall learn more later, electric currents varying according to the vibrations of the diaphragm are transmitted along the telephone wire. These currents cause the diaphragm in the telephone receiver to vibrate in the same way as the one in the transmitter, and air waves are set up corresponding to the air waves produced by the voice of the person speaking into the telephone miles away.

Problem 3. How the ear is fitted to receive sounds. — The way in which the ear is able to receive sound waves may be understood by a study of the diagram showing the arrangement of the parts of the ear. The external portion, which is roughly funnel-shaped, leads into a tube about an

inch in length at the end of which is the ear drum. Beyond the ear drum is the middle ear which connects with the throat by the *Eustachian* (ū-stā′ kĭ-an) *tube*. Across the cavity of the middle ear extends a chain of very small bones, one end of which is in contact with the ear drum, and the other with the membrane of the inner ear. In the inner ear, which is

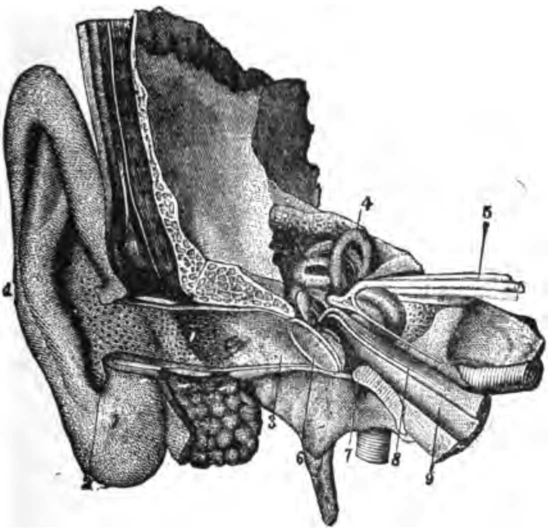


FIGURE 49. — HUMAN EAR.

1, external ear; 2, hairs at entrance of auditory canal; 3, auditory canal; 4, semicircular canal, a portion of internal ear; 5, auditory nerve leading to the brain; 6, ear drum, from which a chain of bones extends to the inner ear; 9, Eustachian tube, connecting the middle ear with the throat.

filled with liquid, are many minute projections of a large nerve, the auditory nerve, which extends to the brain.

Your knowledge of the way in which sound waves act will enable you to explain what goes on in the ear when air waves reach it (Figure 49). What is the advantage of the expanded outer portion of the ear? What effect will

the air waves have upon the ear drum? What is the purpose of the chain of bones in the middle ear? What will happen to the liquid in the inner ear as a result of the movement of the chain of bones? The small nerve filaments are affected by the motion of the liquid surrounding them, and a message is carried to the brain by the auditory nerve. Thus we have the sensation of hearing.

The purpose of the Eustachian tube is to equalize the pressure of the air on the two sides of the ear drum so that it will vibrate freely. Sometimes in yawning you will notice that for a moment you cannot hear distinctly and that you have a peculiar ringing in the ears. This is because the tubes have become temporarily closed. The same condition may arise for a longer time as a result of a cold.

The peculiar feeling in the ears experienced in going up or down in an elevator in a high building or through a tunnel, is due to the fact that the pressure of the air on one side of the ear drum is greater than that on the other. Opening the mouth or swallowing will relieve the pressure. Why? Artillerymen are apt to have their ear drums broken at the time of firing their guns unless they open their mouths. Explain.

Suggested Individual Projects

1. Demonstrate the structure and the method of production of sound by one of the following musical instruments: violin, guitar, banjo, cornet, flute, drum, piano, organ, etc.
2. The dictograph.
3. How the player-piano works.
4. Construct a telephone to be used between two rooms of the school building.
5. Construct a speaking tube between two classrooms.
6. Construct the model of a human ear.

Reports

1. The history of the development of certain musical instruments.
2. Discovery and development of the talking machine.
3. Different kinds of organs of hearing possessed by animals.
4. The Maxim "silencer" for firearms.

PROJECT VI

IMPORTANCE TO US OF OXIDATION (BURNING)

WE realize that burning is of great importance to us when we consider that it furnishes us with heat, light, and power. When properly controlled, it is one of our most useful servants; but when it is uncontrolled, it becomes one of our most destructive enemies.

FIGURE 50. — OIL FIRE.
Burning of a 55,000 barrel oil tank.

Problem 1. What burning is. — We build a bonfire or a fire in a stove for the heat it produces. Fires on hilltops have been used from the earliest times as night signals. What, therefore, may we say, is produced by burning?

If the draft of the stove or furnace is good, the fire burns brightly; if ashes are permitted to collect below the firebox, the fire is likely to go out. What seems to be necessary for burning? Think of other examples of burning that are familiar to you. Does air always seem to be necessary? Is heat or

light produced in every case? The following experiment will show that some of the air is used up in burning.

Experiment. — Place a lighted candle on a cork floating in a pan of water and invert a glass jar over it (Figure 51). After the candle stops burning, the water rises in the jar to take the place of the air that was used up. The part of the air that is used in burning is called *oxygen*, and the uniting of the oxygen with the substance which is being burned (fuel) is called *oxidation.*

FIGURE 51.

Experiment. — To find out if any new substance is produced in burning, burn a piece of charcoal (carbon) over the mouth of a test tube containing lime water. Shake the lime water. What is the result? This milky appearance in the lime water is the test for a gas called *carbon dioxide.*

It is evident, therefore, that in the burning of carbon the carbon disappears and there is produced a new substance called carbon dioxide, a gas made by the combination of carbon with the oxygen of the air. Experiments have been performed which show that the weight of the carbon dioxide formed is exactly equal to the weight of the carbon which was burned plus the weight of the oxygen used. This combination of carbon and oxygen is accompanied by heat and light.

A change in which a new kind of substance is formed is called a *chemical change.*

Carbon and oxygen are simple substances which by no method yet discovered have been separated into anything else. Carbon dioxide, on the other hand, may be shown to be composed of carbon and oxygen combined in a definite proportion. Carbon dioxide is a gas that will prevent burning and is therefore an entirely different substance from its constituents, namely, carbon which is a solid and oxygen which is necessary for burning.

Substances, like carbon and oxygen, which cannot be separated into two or more substances are called *elements*. Some of the common elements are nitrogen, hydrogen, sulphur, phosphorus, iron, copper, sodium, potassium, chlorine, and silicon.

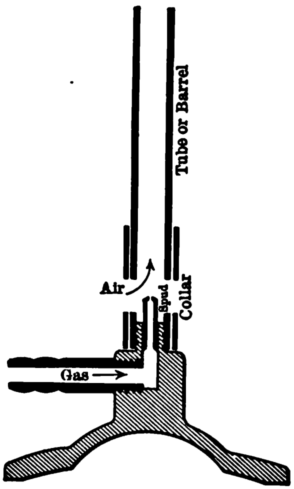


FIGURE 52 a.—BUNSEN BURNER.

Substances like carbon dioxide are called *compounds*. Water is a compound composed of the two elements, hydrogen and oxygen. Starch is a compound of carbon, hydrogen, and oxygen. Limestone is a compound containing the elements, calcium, carbon, and oxygen. Almost all substances we know of are compounds of two or more of about a dozen elements. Altogether about 80 elements have been discovered, but many of these occur in very small quantities or are not found in common compounds.

Explain: (1) The failure of a furnace to burn if ashes are

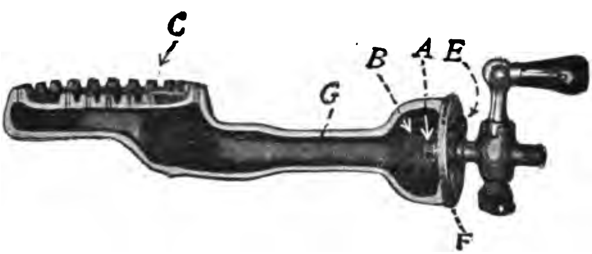


FIGURE 52 b.—GAS STOVE BURNER.

A, gas inlet; *B*, air chamber; *F*, air inlet; *G*, tube containing mixture of gas and air; *C*, outlet of gas mixture.

not removed; (2) The failure of a wood fire to burn if wood is not arranged loosely; (3) The reason for the holes at the base of a lamp or of a Bunsen burner (Figure 52a); (4) Why firemen have more difficulty in checking a big fire when wind is blowing hard; (5) Construction of a gas stove burner (Figure 52 b).

Problem 2. How the power of an automobile is produced. — We all know that gasoline is burned to give the engines of automobiles and motor boats their power. That there

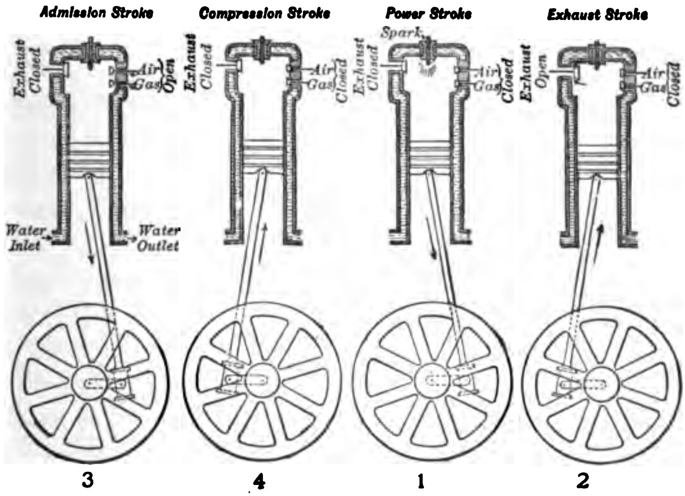


FIGURE 53. — MOVEMENTS OF PISTON OF GAS ENGINE.
Diagram showing how the explosion of a mixture of air and gasoline vapor produces movement in the gasoline engine.

is power developed in the burning of gasoline may be illustrated by a very simple experiment.

Experiment. — Make a hole in the side of a coffee pot or a can with hinged lid, a short distance from the bottom. Into the can pour a

few drops of high grade gasoline and close the lid. Put a burning match or taper through the opening at the side. An explosion will occur which lifts the lid.

In the gas engine, a mixture of gasoline vapor and air compressed in the cylinder is exploded by a spark from the spark plug and the piston is thrown back with great force (Figure 53). By means of a crank shaft and the gears this power is made to turn the rear wheels of the automobile or the screw of the motor boat.

Explain: (1) The striking back of a Bunsen burner (Figure 52 a); (2) The popping of a gas grate or gas stove when lighted (Figure 52 b).

Problem 3. How a match is lighted. — Explain what you usually do to light a match. Can you light a match without rubbing it over a somewhat rough surface? What do you think was the reason for rubbing the match over a rough surface?

Can you light a piece of wood in the same way that the match was lighted?

Compare the head of the match with the wooden stick as to the ease of starting it to burn. What then is the reason for the head of the match (Figure 54)?

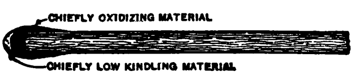


FIGURE 54. — A MATCH.

Since the head of the match starts to burn at a much lower temperature than wood, it is said to have a lower kindling temperature. How would you define kindling temperature?

The head of the ordinary parlor or friction match is usually a mixture of (1) phosphorus and a substance which readily gives out oxygen, (2) some ground glass to increase

friction, (3) glue, and (4) coloring matter. The stick is dipped into paraffin before the head is put on.

You can now give the steps in the lighting of a match. What does the rubbing or scratching of it on a rough surface do? What is the effect of the burning of the phosphorus upon the paraffin? What is the effect of the burning of the paraffin upon the wood of the match stick? The flame is caused by the burning of the gases which are given off when the wood is highly heated.

Since ordinary friction matches are a great source of danger from fire, efforts have been made to produce a match that is less dangerous. One method has been to coat the sides of the head with a substance that has a relatively high kindling temperature. The "birds-eye" matches are of this type. To lessen the danger from fire, the "safety" match also has been invented. You are all familiar with the matches which will not usually light unless scratched upon a special striking surface. The heads of these matches contain a substance which gives out oxygen when heated but contains no phosphorus, the phosphorus mixture being in the striking surface on the side of the box.

You will notice that some match sticks do not continue to burn until the entire stick has burned up. This is because the sticks have been soaked in a liquid that hinders burning. Explain the great value of this.

Formerly the manufacture of matches was a very dangerous occupation as the white or yellow phosphorus used poisoned the workers, especially affecting the jaw bones. The use of this form of phosphorus has now been prohibited in practically all civilized countries, and either red phosphorus or a compound of phosphorus and sulphur, both non-poisonous, is used in production of matches.

Explain: (1) The lighting of a gas jet; (2) the starting and continued burning of a coal fire; (3) The difficulty of lighting a match when the wind is blowing.

Problem 4. What causes iron to rust. — This question may be answered by performing the following experiment.

Experiment. — Put into a test tube a small quantity of iron filings and a few drops of water. Move the test tube around until the moist iron filings form a layer sticking to the inside of the tube. Place the test tube, mouth down, in a glass of water. Note how much of the tube is filled with air. Examine again on the following day.

FIGURE 55. — RUSTING OF IRON.

Experiment. — Test the air that remains in the test tube for the presence of oxygen. This may be done as follows: Keeping a finger over the bottom of the test tube turn it so that the mouth is up. Insert into the air in the test tube a lighted splinter or taper. Does the taper continue to burn? What does this prove? What, therefore, do you think happens in the rusting of iron?

Can you suggest a reason for not noticing any heat or light? It is evident that some cases of oxidation are relatively slow. It is interesting to note that moisture also is necessary for the rusting, so that this process of oxidation is not quite so simple as some of the other cases which have been mentioned.

In addition to the rusting of iron there are many other common happenings which are the result of slow oxidation.

Rub a match over the hand in the dark. What do you observe? If paint containing linseed oil is allowed to stand a short time, a tough skin is formed on its surface. This is caused by slow oxidation of the oil in the paint. The same thing happens when the paint is spread upon a surface. The "drying" of such paint is due to oxidation, and not to real drying.

Oily rags which have been thrown together in a heap sometimes catch fire. What is the explanation of this fact?

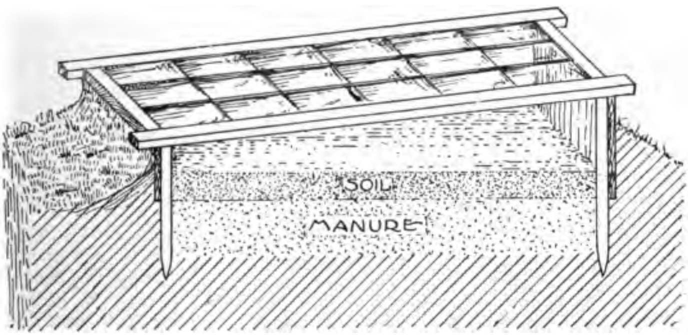


FIGURE 56. — SECTIONAL VIEW OF A HOTBED.

The oil slowly oxidizes and the heat which is produced gradually increases until the temperature has been raised to the kindling point. The whole mass will then break into flames. This is called *spontaneous combustion*. Why does oily clothing not catch fire spontaneously if hanging?

It is not an uncommon occurrence in the country for a barn filled with slightly damp hay to catch fire. In this case the production of heat is probably hastened by the action of small living plants, called *bacteria*, which are present on the stems of the grass or come from the air. The hay does not give off the heat readily, and finally, as in the case of

the oily rags, sufficient heat accumulates until the kindling point is reached.

The heat produced in a *hotbed* is formed in the same way as the heat was produced in the hay barn, but it does not reach the point where the oxidation becomes rapid enough to give off light. A hotbed is made of decomposing organic matter, usually a mixture of straw and horse manure.

Figure 57. — Factory Wrecked by a Dust Explosion.

This is covered with a layer of soil. The bed is inclosed with frames of glass or cheesecloth to prevent the escape of the heat produced (Figure 56). The hotbed is used for forcing the early growth of plants.

Explosions occur in poorly ventilated coal bunkers and flour warehouses (Figure 57). How can you account for this? Why is the fineness of the dust particles a factor? Why is an explosion not apt to occur unless the ventilation is poor?

Problem 5. Why coal is burned. — Enormous quantities of coal are used every year. A coal famine is a very serious matter. During the winter of 1917–18 many cities suffered from shortage of coal. In many cases theaters, schools, and libraries were closed; and factories were shut down, throwing thousands of people out of employment. Transportation facilities were interrupted; the use of lights was very much restricted, resulting in much inconvenience and loss.

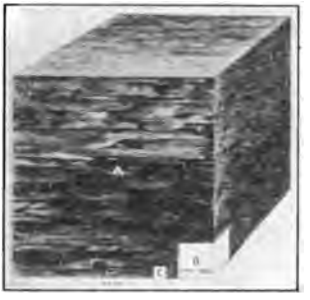


FIGURE 58. — AVAILABLE COAL SUPPLY.

A, dimensions 10 miles along each edge, represents the total coal resources of United States: *B*, the exhaustion to close of 1911; *C*, production in 1911.

In your own home or apartment building, coal is burned for production of heat. But in many cases, the production of heat is not the final result desired. In the steam engine, the heat produced by the burning of the coal is used to change water into steam which gives the engine the power to do many things. What are some of the things which steam engines can do? Most electric power houses have great steam engines which are used for the generation of electricity. Therefore, from what source may electrical power be obtained? What are some of the things that electricity can do? To what power, therefore, may all these things be traced?

It will thus be seen that heat, light, electrical and mechanical power may be changed one into another. They are different forms of energy. *Energy* may be defined as the capacity for doing work.

Suggest specific examples which are known to you of the change of one form of energy into another.

FIGURE 59. — COAL FIELDS OF THE UNITED STATES.

What is your conclusion as to why coal is burned? Name other substances which are burned for this purpose. These various substances are called *fuels*. What is your definition of a fuel?

Problem 6. How available energy is supplied to the human body. — How can the energy in our bodies and in the bodies of animals be explained? Every movement of our body demands muscular energy. If your body weighs one hundred pounds, every time you take a step you must lift one hundred pounds. Energy is needed even for the beating of the heart, for the digestion of food, and for the other involuntary activities of the body.

If you will think of all the activities of the body at work and play during the day, you may realize to some extent the need of the body for energy. In addition to this energy, the temperature must be kept at about 98.6 degrees Fahrenheit, winter and summer, day and night, in spite of the constant losses of heat from the body.

Judging from the way that energy is made available in engines and machines, what do you suspect to be the source of the energy of the human body? The correctness of your answer can be tested. If it is correct, oxygen must be taken into the body, a constant supply of fuel must be furnished, and carbon dioxide must be given off.

Evidently the air which we breathe in must furnish the oxygen. Does the air breathed out contain an increased amount of carbon dioxide? This may be found out by the following experiment.

Experiment. — Put some lime water into a test tube and breathe into it through a glass tube. What is the result? You will remember that a milky appearance indicates the presence of carbon dioxide. Conclusion?

Careful analysis shows that expired air (air breathed out) contains about 25 per cent less oxygen than inspired air (air breathed in), with a corresponding increase of carbon dioxide.

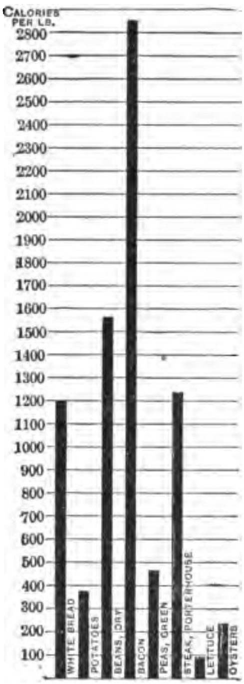


FIGURE 60. — FUEL VALUE OF SOME COMMON FOODS.

A calorie is the amount of heat necessary to raise the temperature of 1 kilogram of water 1° centigrade.

What constitutes the fuel in the body? — It is the food. Just as you may obtain heat and light and power to run engines by the burning of oil, so in the body the fat, a form of oil, is burned to produce heat energy and muscular energy. Light is not produced, since the process goes on too slowly. Likewise, other food materials are burned in the body to produce energy (Figure 60). An ounce of fat or starch burned inside of the body will furnish the same number of heat or energy units as if it were burned outside of the body.

Sum up now your conclusions as to how energy is made available in the human body. Compare this process in the human body with what goes on in the fire box of a furnace or engine.

Why does a man working hard need more food than one who is not performing hard muscular work?

Why do we eat more food in the winter than in the summer?

By carefully taking temperatures, it has been shown that the energy is set free in the part of the body that is active; chiefly of course in the muscles.

Why do the muscles of the body which are used most not become overheated? The circulating blood is constantly receiving heat from the more active parts of the body, and is giving it to those parts which are less active. As a result, the temperature of the body is equalized. Since the heat energy and muscular energy are made available in the various parts of the body, three other uses of the circulating blood are indicated. What are they?

Problem 7. Do plants breathe? — If they do, then there must be some proof that three different things occur. What are they?

To find out if plants use oxygen and give out carbon dioxide perform the following experiment.

Experiment. — Into each of two flasks put an equal number of peas that have been soaked in water. Cork one flask so that no air can pass into it or out of it. Allow the other flask to remain open. Place the flasks side by side so that they will have the same conditions of light and heat. At the end of a week observe the contents of the flasks.

What has happened? What does this prove? A blazing splinter passed into the open flask continues to burn. What happens when it is passed into the flask which has been kept closed? What does this prove? If the air in each flask is tested for the presence of carbon dioxide, it will be found that the closed flask contains a considerable amount of carbon dioxide while the other does not contain an appreciable quantity. What does this prove? What is your general conclusion as to the use of oxygen by sprouting seeds?

If oxidation goes on in sprouting seeds we should expect that heat and energy of movement would result.

Experiment. — Into a flask put an inch or more of pea seeds which have been killed by being heated for a short time in an oven. Into another flask put an equal amount of living pea seeds. Put into each flask the same amount of moisture. Place a thermometer in each flask, covering the mercury bulb with the peas. Permit free access of air. From time to time note whether the thermometers register a difference in temperature.

It will be found that heat is generated by the sprouting pea seeds. What observations have you made that will

FIGURE 61. — FLOODED REGION.
Trees killed by having their roots drowned.

show that sprouting seeds are able to lift a weight or in other ways exert mechanical energy?

Seedlings take in the oxygen of the air and give off carbon dioxide through any part of their surfaces. In fully grown plants this occurs chiefly through the young roots and leaves. In a region flooded for a considerable time, the trees will

die, chiefly because their roots have been unable to get oxygen from the air (Figure 61). They have been drowned.

Problem 8. How animals take in oxygen and give off carbon dioxide. — Animals have various ways of taking in oxygen and giving off carbon dioxide.

(*a*) *Very simple animals.* — Earthworms and other simple animals have no lungs. How then do you suppose they can take in oxygen? Plants, we already know, breathe

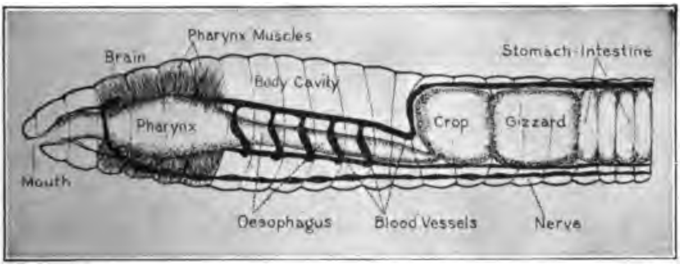


FIGURE 62. — ORGANS OF AN EARTHWORM.

Many small blood vessels (not represented in the figure) pass from near the surface of the body into the large vessels, which are also near the surface.

through thin moist membranes. Possibly this is true of the earthworm. If so, the earthworm must have a thin moist skin. Examine an earthworm to see if this is the case. An earthworm dies as soon as its skin becomes dry. Frequently after a rain, many earthworms come to the surface because their burrows have become filled with water. Early in the morning they may be seen crawling on the sidewalk, but it will be noticed that they die as soon as the sun has dried their bodies.

If an earthworm breathes through its skin, what should be directly below the thin moist membrane of the skin?

Sum up your conclusions as to how the earthworm takes oxygen into its body and gives out the carbon dioxide.

(*b*) *Insects* cannot breathe through the skin. Why not? If a grasshopper is watched, it will be noticed that the hinder portion of the body (abdomen), which is made up of rings, expands and contracts in a way similar to the expansion and contraction of our own chests during breathing. These movements of the grasshopper are breathing movements.

The air containing oxygen goes into the body with each expansion, and the air containing carbon dioxide passes out at each contraction. Where does the air go in? If you look very carefully along each side of the body you will see a number of small holes, one in each of the divisions of the abdomen. There are also two pairs of holes in the thorax, the part of the body to which the legs and wings are attached. Connected with these openings are small branching tubes which carry air to all parts of the body.

These breathing pores can usually be seen very distinctly on the sides of a beetle larva (Figure 63) or of a caterpillar, which you know, of course, is the young of a moth or butterfly. The young or larva of the mosquito which lives in water has only one breathing pore, which is located at the tail end of the body. In order to get air, it must come to the surface hanging head downward.

Mosquitoes, therefore, may be destroyed by pouring oil on ponds in which they live. The oil spreads over the surface of the water, forming a thin layer through which air will not pass. Thus the mosquito larvæ are unable to obtain air when they come to the surface, and suffocate.

(*c*) *Fish* breathe by means of gills which are located under flaps just back of the head. If you examine a fish which has been sent from the market with the head still attached,

you will see under these flaps (opercula) four bony arches on each side. Between these arches are slits opening into the back of the mouth. Each arch has upon its outer edge a large number of small, reddish, threadlike structures, (gill-filaments) which project backward from the arch. The inner side of each arch has on it a number of hard, pointed structures (gill-rakers) (Figure 64).

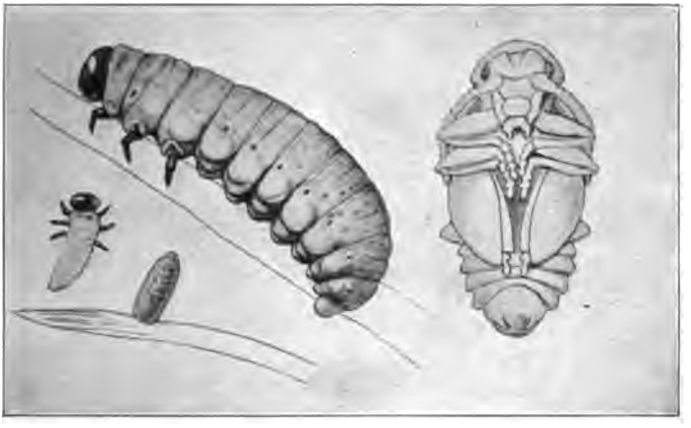


FIGURE 63.—STAGES IN THE LIFE HISTORY OF A BEETLE.
Note the breathing pores on the side of the larva (the worm-like stage).

Observe a fish in an aquarium. Do you notice any movements which are probably connected with breathing? Water passes into the mouth of the fish and out through the gill slits at the side of the head. Suggest a use for the gill rakers. The heart is located on the under side of the fish, in the space between the back parts of the gills. It pumps the blood forward through a vessel which has four branches on each side, one to each gill arch. These vessels in turn send off very small vessels into the gill filaments.

What do you suppose the blood in these vessels receives?

What does it give off? The blood from the gill filaments passes into vessels which carry it to the upper part of the gill arches and from there it passes to all parts of the body, finally returning to the heart loaded with carbon dioxide and without its oxygen. What has become of the oxygen? What is the source of the carbon dioxide?

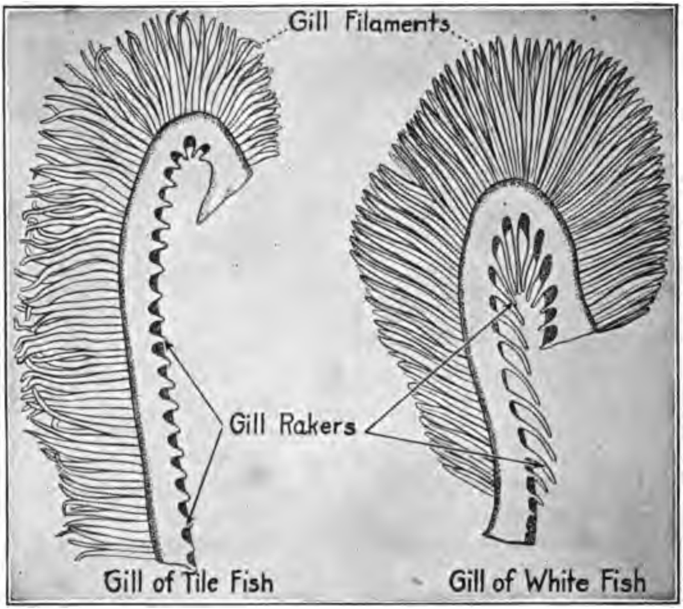


FIGURE 64. — BREATHING ORGANS OF FISH.

(*d*) *Higher animals.* — Most animals that live in the air, except insects, breathe by means of lungs which are really thin-walled bags connected with the outside air through the nostrils. The walls of the lungs contain many small blood vessels (capillaries). The blood in these takes in oxygen and gives off carbon dioxide.

Individual Projects

1. Production of pure oxygen and comparison of the burning of substances in air and in oxygen.
2. Making a safety match.
3. Demonstration of how the explosion of gasoline causes the gas engine to work.
4. Demonstration of how air and gas are mixed in a gas stove.
5. Construction and use of a hotbed.
6. Making gas from coal and wood.
7. Collection of various kinds of coal. Source and special use of each kind.
8. Dissection of the blood system and breathing system of a fish.

Reports

1. History of the discovery of oxygen.
2. The coal regions of the United States, methods of mining, and approximate number of years our supply will last.
3. Formation of coal.
4. Different ways in which animals breathe.

References for Project VI

1. Book of Wonders, Bodmer, R. (Fire.)
2. Chemical History of a Candle, M. Faraday. Harper & Bros.
3. Fuels of the Household, Marian White. Whitcomb & Barrows, Boston.
4. Sweden and Safety Matches, N. B. Allen. Ginn & Co.
5. Diggers in the Earth, E. M. Tappan. Houghton Mifflin Co. (Coal mining.)
6. Earth and Sky Every Child Should Know, J. E. Rogers. Doubleday, Page & Co.
7. The United States, J. O. Winston. D. C. Heath. (Coal.)
8. The Story of Oil, W. S. Tower. D. Appleton & Co.
9. Field and Forest Handy Book, Beard. Scribners. (Camp cooking and stoves.)
10. American Inventions and Inventors, Mowry. Silver, Burdett & Co. (Fire, Fuel, Matches.)

PROJECT VII

PREVENTION OF DESTRUCTIVE BURNING OR OXIDATION

We have seen that oxidation is very valuable in giving us usable energy. Can you name examples of oxidation or burning which are harmful? From what we have learned

FIGURE 65. — RESULTS OF A FOREST FIRE.

Not only have the trees been destroyed but almost all the vegetable matter (humus) of the soil has been burned away.

about burning, we should be able to suggest means by which destructive oxidation may be prevented.

What two conditions are always necessary for oxidation? Suggest another which is usually necessary. It is clear that if any one of the necessary conditions is removed, then

burning or oxidation must stop. Our problem then is simply to discover methods by which these conditions necessary for oxidation may be prevented.

Problem 1. How destructive oxidation may be prevented by excluding the air.— (*a*) Coating iron with a substance which does not rust. What are some of the ways in which air may be kept from substances which are apt to undergo harmful oxidation? How are iron fire escapes kept from rusting? Give other examples of the use of this means.

Is a tin pan made entirely of tin? Give proof for your answer. Tinware is made of thin sheets of iron which, after having been thoroughly cleaned, are dipped into melted tin. Iron also may be prevented from rusting by covering it with a layer of zinc, applied in the same way. This is called *galvanized iron* and is very generally used for pails, water troughs, and similar articles. It is not used for cooking utensils, as zinc may form poisonous compounds.

How is the iron hot water boiler in the kitchen prevented from rusting? It is usually painted with a volatile substance (a substance which evaporates quickly) in which there is powdered aluminum, a metal which is not affected by the air. The volatile liquid disappears, leaving on the boiler a thin layer of powdered aluminum which not only gives the boiler a pleasing appearance but also prevents it from rusting.

Iron may also be prevented from rusting by covering it with a layer of nickel, which is put on by the use of electricity (nickel plating).

The iron of stove pipes and locomotive boilers is usually protected from rusting by a coating which is produced by passing over the hot iron a mixture of highly heated steam

and carbon dioxide. This coating is an oxide of iron, different from the ordinary oxide of iron, and it protects the iron from further oxidation. Iron, coated in this way, is called *Russia iron.*

(*b*) *How do fire extinguishers work?* — A fire is put out by surrounding the burning material with a gas which will not burn. What happens then to the fire? Some fire extinguishers contain a liquid, carbon tetrachloride, which becomes a non-inflammable gas when it is squirted on the fire. In the fire extinguishers which are inverted just before being used, sulphuric acid falls into a solution of soda (Figure 66). The action of the acid upon the soda produces a large quantity of carbon dioxide which forces out the mixture of water and carbon dioxide. What effect will this have when played upon the burning objects?

FIGURE 66. — FIRE EXTINGUISHER.

Explain the reason for keeping pails of sand in various parts of a garage. Why is water not used for the purpose? Will water mix with gasoline?

(*c*) *Smothering a fire.* — Explain why it is advisable to roll a person whose clothing is on fire in a rug or blanket. Is it advisable for a person to start to run if his clothing is on fire? Why? Why are burning draperies pulled down and stamped upon?

Problem 2. How destructive oxidation may be prevented by reducing the temperature below the kindling point. — Throwing water on a fire, you all know, is the usual way of putting it out. Why do you suppose it is so effective? Do you think that the amount thrown by the firemen upon a big fire will prevent the air getting to the fire? Why, then, is water so valuable for putting out a fire? Reference to your study of ventilation will help to answer this question. What was the effect of evaporation of moisture on the skin? What becomes of the water that is thrown on the fire? What effect will this have upon the temperature? A wet piece of wood does not burn readily because the heat applied is used in evaporating the water instead of raising the wood to its kindling temperature.

FIGURE 67.— FIGHTING A FIRE WITH WATER.

Sum up your conclusions as to the importance of water in lowering the temperature of a burning substance below the kindling temperature. Do not forget that the water and steam produced are also useful in preventing the access of air.

Problem 3. How destructive oxidation may be prevented by removal of fuel material. — No fire can start or

continue to burn unless there is a supply of fuel material; hence, the inspectors of the fire department prohibit the collection of rubbish in basements and area ways. Every year forest fires destroy property worth hundreds of thousands of dollars and cause the death of many people. Probably the most common cause of these fires is the carelessness of campers in failing to put out their camp fires. Very

FIGURE 68. — A FOREST FIRE FIGHTER.

strict regulations concerning the use of fire are enforced to prevent the starting of forest fires. To limit the spread of a fire if once started in a forest reservation, there are *fire lanes* which are kept cleared of underbrush. Why do the fire lanes stop the fire?

Ground fires which creep along the ground, depending for fuel upon the underbrush and vegetable matter accumu-

lated during many years, are frequently stopped by plowing up a strip of land in the path of the fire. What is the advantage of this?

During severe fires in cities which threaten to destroy property in great areas, buildings are often deliberately destroyed by dynamite. What is the reason for this? Where there are buildings in solid blocks, fireproof walls are constructed at intervals which are known as *fire walls.*

What is meant by fireproof construction of buildings? In what respect is your school building of fireproof construction? In other buildings with which you are familiar, what means have been taken to make them fireproof? What substances may be used in fireproof construction?

FIGURE 69. — FOREST RANGER ON LOOKOUT FOR SIGNS OF FOREST FIRES.

If signs of fire are discovered, the ranger telephones to the fire station nearest the fire, indicating by reference to the forest map the exact location of the observed smoke.

INDIVIDUAL PROJECTS

1. Make and demonstrate a fire extinguisher.
2. Collection and demonstration of fireproofing materials.

REPORTS

1. Fighting a forest fire.
2. Fireproof construction of buildings.

PROJECT VIII

IMPORTANCE TO US OF THE OTHER GASES OF THE AIR

We have seen that the oxygen of the air is of very great importance to us. Mention several ways in which it is of great value and several in which it is harmful. The question naturally arises, are there other gases in the air and if so, of what importance are they to us. The first problem therefore is:

Problem 1. Does air contain any gas besides oxygen?

Experiments. — (1) Burn a taper in air, and then in oxygen.

(2) Burn in oxygen a bundle of fine iron wire, dipped in sulphur. What are the results? What is the conclusion?

(3) Expose a vessel of limewater to the air. Note that a scum appears on the surface. This is an indication of the presence of carbon dioxide.

Problem 2. How much of the air is oxygen? — Can you suggest a method by which this may be found out?

Experiment. — On a metal disk on a flat piece of cork, place a bit of yellow phosphorus. Place the cork on water and invert over it a glass cylinder. Examine after two days. Result? Conclusion?

Quantitative experiments have shown that air has the following composition:

Oxygen, 20+ per cent.

Nitrogen, including several inert gases, 79+ per cent.

Carbon dioxide, .03 to .04 of 1 per cent.

Problem 3. Importance of nitrogen in the air.

Experiment. — Manufacture some oxygen. This can be done by heating a mixture of potassium chlorate with manganese dioxide in a flask. The gas can be collected in a bottle in the manner shown in the diagram (Figure 70). Burn various substances as wood splinters, a candle, some sulphur, and an iron wire in bottles of pure oxygen.

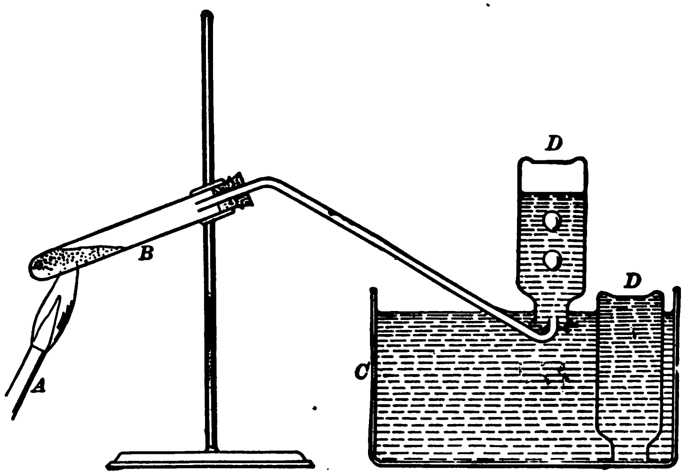


FIGURE 70. — PREPARATION OF OXYGEN.

A, bunsen burner; *B*, tube containing potassium chlorate and manganese dioxide; *C*, vessel containing water; *D*, *D*, bottles for collecting gas.

Pass oxygen into a bottle until it is one fifth filled. Fill the remainder with nitrogen, which may be made by heating together in a flask the two chemicals, ammonium chloride and sodium nitrite. Try to burn in this mixture of oxygen and nitrogen a splinter of wood, a candle, some sulphur, and an iron wire. Do these substances burn the same as when burned in the pure oxygen?

What would happen if the air contained a much larger percentage of oxygen? What do you consider to be the value of nitrogen in the air? Nitrogen is a very inactive substance. It is due to this property that nitrogen is an

important element in explosives. Explain. Under certain conditions some of the nitrogen of the air may be used in the growth of plants or may be made into substances from which explosives may be manufactured. These cases will be considered later.

Problem 4. Importance of carbon dioxide of the air. — We found that certain animals in breathing give carbon dioxide to the air. Also that it is added to the air in the burning of a candle. In the same way it is given off in the burning of coal, wood, oil, etc. As a result what do you think should happen to the amount of carbon dioxide in the air? But an examination of the air year after year indicates that there is no increase in the amount of this gas. What do you conclude from this?

Another interesting fact gained from the examination of the air is that the oxygen of the air does not decrease in quantity. In the solution of our problem, therefore, a number of smaller problems must be solved. The first of these will be indicated by a fact that is familiar to you. What is the appearance of partially burned plant material? What does this indicate? Since plants can grow in soil which contains no carbon, what will you suspect is the source of the carbon?

Sub-problem I. Proof that carbon compounds are made in leaves of plants. — One of the most common plant substances containing carbon is starch. There is no starch in the soil or in the air, therefore it evidently must be made within the plant.

Experiment. — To prove that starch is manufactured in a leaf place a geranium in a dark closet for twenty-four hours, then remove a leaf and test for starch. This is done by first removing the green col-

oring matter, by soaking the leaf in alcohol, and then adding iodine, which gives a blue color if starch is present. What is the result? After this leaf has been removed, set the entire plant in the sunlight, first placing upon several leaves pieces of black cloth or thin strips of cork which completely exclude the light from the portions of the leaves covered. After a few hours, remove and test several leaves for the presence of starch. What is the result? What two things are proved by this experiment?

FIGURE 71. — POTATO PLANT.
A plant in which a large amount of starch is stored in an underground stem.

Sub-problem II. What raw materials are used by leaves in making starch? — Analysis shows that starch is made of the following fundamental substances or elements: Carbon, 6 units; hydrogen, 10 units; oxygen, 5 units. This is conveniently written, $C_6H_{10}O_5$. Water, which is made of two units of hydrogen and one unit of oxygen (H_2O), and carbon dioxide, composed of one unit of carbon and two units of oxygen (CO_2), both of which are accessible to the leaf, contain the elements necessary for the formation of starch. If they were combined, the result might be represented as follows: Carbon dioxide (CO_2) + Water (H_2O) = Starch ($C_6H_{10}O_5$). It will be noted that to get sufficient

carbon for the starch, it is necessary that six units of carbon dioxide enter into the combination; and to provide the proper proportion of hydrogen, five units of water must combine with the carbon dioxide. The action may then be represented as follows: six units of carbon dioxide might combine with five units of water to form one unit of starch or

$$6\ CO_2 + 5\ H_2O = C_6H_{10}O_5$$

But if six units of CO_2 unite with five units of H_2O to form starch ($C_6H_{10}O_5$), it will be noticed there is an excess of oxygen, so that the action will finally be represented as follows:

$$6\ CO_2 + 5\ H_2O = C_6H_{10}O_5 + 6\ O_2$$

If in the leaf, therefore, carbon dioxide and water actually do unite in forming starch, oxygen should be given off. Does this occur?

Sub-problem III. Do plants give off oxygen in making starch?

Experiment. — Place some aquarium plants under a funnel in a jar of water. Over the neck of the funnel put an inverted test tube filled with water. Place the jar in the sunlight. What do you observe?

Remove the test tube without allowing any of the contained gas to escape, and pass into the mouth of the test tube a glowing ember. What happens? What does this prove?

The work that the green leaf does with the assistance of sunlight in combining carbon dioxide and water into starch is called *photosynthesis* (from two Greek words: *photo*, light, and *synthesis*, putting together).

Sub-problem IV. Proof that plants use carbon dioxide in making starch. — The fact that oxygen is given off by plants is an indication that carbon dioxide and water are

used by the plant in making starch. It can easily be proved by the following experiment that carbon dioxide is used by plants during the process of starch-making.

Experiment. — Pass into a jar sufficient carbon dioxide to replace the air almost entirely. Put into the jar a green plant which has been kept in the dark for twenty-four hours. Pass a lighted taper into the jar. What is the result? Also pass into the jar a glass rod from which is hanging a drop of limewater. What is the result? Cover the jar tightly and place it where it will be exposed to sunlight. After several days again test the contained air with the limewater and the lighted taper. Results? Conclusions?

Sub-problem V. Amount of carbon dioxide removed from the air in making starch and wood. — The woody substance of plants (cellulose) is also made of carbon, hydrogen, and oxygen in the same proportion as in starch. Wood, therefore, represents a certain amount of carbon dioxide taken out of the air and combined with water. It has been calculated that for every pound of starch or cellulose (wood manufactured by a plant) 1.6 pounds of carbon dioxide are needed. From an acre of ground several tons of dry hay may be obtained. A large proportion of the dry hay is cellulose, or material of a similar composition. Considering this fact, calculate approximately how much carbon dioxide will have been taken from the air by a ten-acre field of hay during one season.

The coal which we burn has had a similar origin. It was formed from many generations of plants which formed layer after layer of vegetable matter. This was partially oxidized and then was covered by sediment which finally became formed into rock. Soft or bituminous coal clearly shows the layers of vegetable matter of which it is composed.

Soft or bituminous coal occurs in great beds usually more

or less horizontal (Figure 72). Anthracite or hard coal is found in portions of the country where the strata or layers of the rock have been very much crumpled. This crumpling process has evidently been accompanied by a high temperature which has driven from the accumulated vegetable matter many compounds, leaving almost pure carbon.

Just as we have found that the starch is made by plants, only under the action of the energy of sunlight, so likewise

FIGURE 72. — COAL BED.
Horizontal bed of coal exposed along a river bed in Wyoming.

in the cases of wood and coal the energy of the sun has been necessary. What, therefore, may be considered to be the final source of the energy given out in the process of the burning of wood or coal? The amount of heat procured by burning a piece of coal may be considered to be a measure of the amount of the sun's energy necessary to separate the carbon from the oxygen of carbon dioxide in the process of photosynthesis (Figure 73).

We are now able to understand why the relative quantities of oxygen and carbon dioxide in the air remain the same year after year.

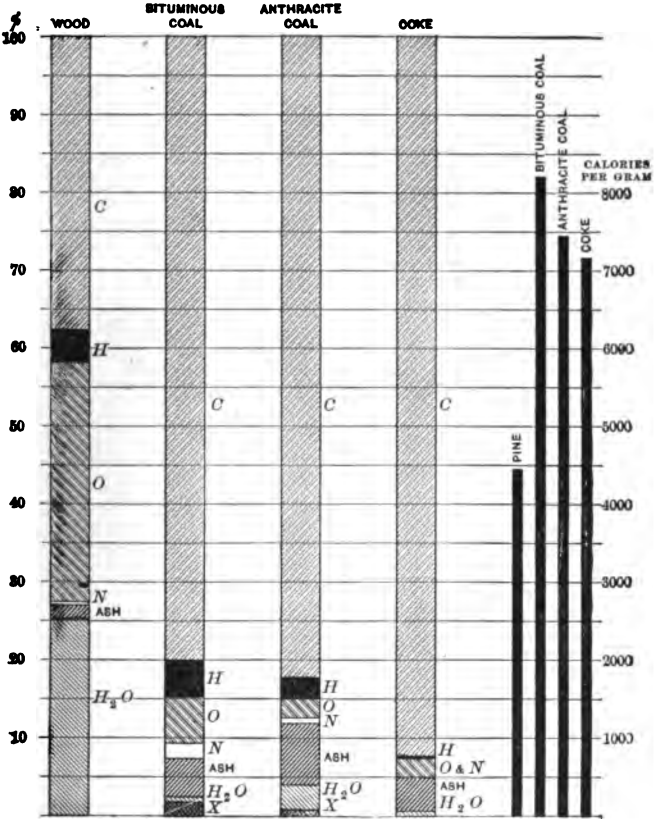


FIGURE 73. — HEATING VALUE OF SOME COMMON FUELS.

Note the relative amounts of carbon (*C*) in the various fuels. What is the source of this carbon? What is the source of the hydrogen (*H*)? The calories given here are small calories. The amount of heat necessary to raise the temperature of one gram of water 1° C. is one calorie. Fuel value of foods is usually given in large calories, 1000 times greater than small calories.

What are the chief ways in which oxygen is removed from the air?

How is it restored to the air?

How do you suppose the composition of the air before the carboniferous period (the period when most coal was formed) differed from the composition of the air now?

FIGURE 74. — OIL WELLS IN OKLAHOMA.

These wells tap oil deposit 2000 to 3000 feet below the surface. Since petroleum has evidently been formed from plant and animal material, what is the source of its energy?

Almost all plants are green. Is there any connection between the possession of this green coloring matter (chlorophyll) and the ability to make starch?

Sub-problem VI. Is the green coloring matter (chlorophyll) necessary for making starch. — Place a plant whose leaves have white streaks or spots (Tradescantia is a good plant to use) in the sunlight for several hours. Test

the leaves for starch. Result? Conclusion? Experiments might also be performed which show that it is only the living leaf that will manufacture starch.

Sub-problem VII. How fish live in a balanced aquarium. — Fish and other animals may be kept for long periods of time without being fed if they are in aquaria containing green plants. In such aquaria the green plants do not decrease in quantity. These aquaria are known as balanced aquaria (Figure 75).

Courtesy of New York Zoölogical Society.

FIGURE 75. — A BALANCED AQUARIUM.

(*a*) *Breathing.* — From what you have already learned, explain how the fish get a supply of oxygen. What do you suppose becomes of the carbon dioxide produced?

(*b*) *Food Supply.* — In a balanced aquarium, what do the fish eat? A fish or any other living thing needs food not only to furnish fuel which may be oxidized to set energy free, but it must also have food to replace the waste which is occurring in the different parts of the body, and for growth if there is any growth going on.

Foods, therefore, may be divided into energy-producing foods and tissue-forming foods. The tissue-forming portion of foods is made up of complex substances called pro-

teins and certain mineral salts. The proteins, when oxidized, will produce energy, but the chief energy-producing portions of food are carbohydrates (starch and sugar) and fats.

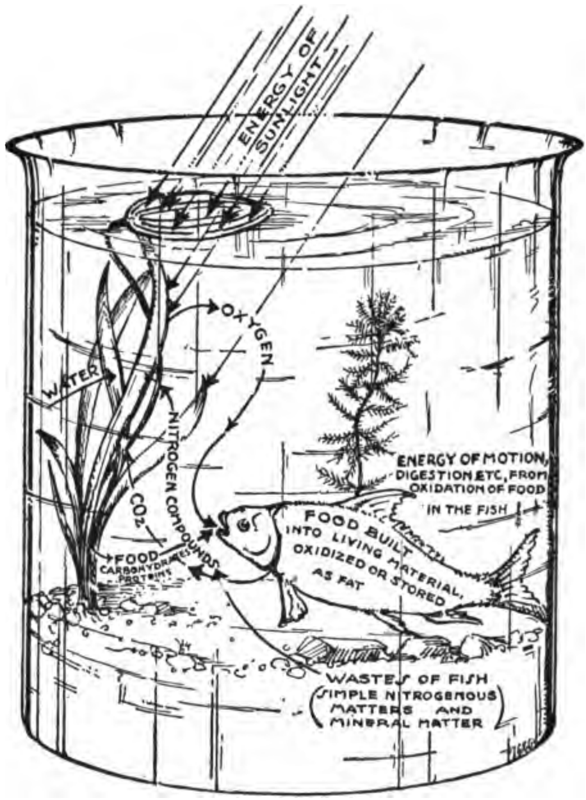


FIGURE 76.—RELATION OF PLANT AND ANIMAL IN A BALANCED AQUARIUM.

Since fish of the balanced aquarium maintain their size and are active, what must be obtained from the plants?

Since the plants do not decrease in quantity, what must they be able to do?

We already have learned from what they make carbohydrates. Explain. Carbohydrates in turn are sometimes changed by the activity of the living matter into fat. For the manufacture of proteins, the plant must not only have carbon, hydrogen, and oxygen, which may be obtained from the carbon dioxide and water, but must also have nitrogen and other elements. The wastes of the fish contain all these needed elements.

In swimming about, the fish are continually exerting energy. What is the final source of this energy?

The relation of the plants and animals in the balanced aquarium is represented in the diagram (Figure 76) on the preceding page.

What do you think would happen to animals, including man, if there should be no more green plants? Explain.

Summarize in a sentence or two the importance to us of the carbon dioxide of the air.

Individual Projects

1. Rapidity of starch manufacture in a leaf.
2. Keeping a balanced aquarium.

Report

The world's food supply.

References for Project VIII

1. The Fresh Water Aquarium and Its Inhabitants, Eggeling and Ehrenberg. Henry Holt & Co.

2. Life in Ponds and Streams, W. Furneaux. Longmans, Green & Co.

3. The American Boys' Handy Book, Beard. (Fresh water and Marine Aquaria.)

PROJECT IX

TO KEEP FOODS FROM SPOILING

You know that many foods if left in the air spoil or decay. Name some foods which you know will spoil if left exposed to the air. Since foods must be transported long distances and frequently must be kept many months before being used, the problem of preserving foods is of the very greatest importance. Without the means of preserving food from decay our present civilization could not have arisen.

Think for a moment of the possibility of the existence of great cities, like New York, Chicago, or of great manufacturing centers, if ways of keeping foods from spoiling had not been discovered. Could the United States have sent her great army of 2,000,000 men to Europe, if there had been no means of preserving foods for many months and even years? In considering how foods may be kept from spoiling, naturally the first problem is:

Problem 1. What causes foods to spoil or decay? — Is it the oxygen of the air acting upon the food which causes the change, a process of slow oxidation such as we have observed in a number of cases? The question can be answered by performing the following experiment.

Experiment. — To find out what causes foods to spoil when left exposed to the air, pour some beef tea made of beef extract and a small amount of peptone (digested protein) into two test tubes. Boil the beef tea in each test tube for an equal length of time. Stopper one with cotton. Allow the other to remain open. Place the tubes side by side in the room. (Experiments have proved that air will pass

through a cotton stopper but that particles floating in the air are caught by the cotton.)

After a few days observe the contents of the tubes. What differences in appearance are noticeable? Smell the contents of each tube. What is your conclusion? Is oxygen alone able to cause substances to decay? If a drop of the beef tea from the unstoppered tube is examined with a high power microscope, a very large number of exceedingly small objects will be seen. Some are spherical and some are rod-shaped.

If even the smallest possible amount of the spoiled beef tea is added to the unspoiled, stoppered tea, the latter also becomes spoiled in a few days. Another examination of the tea with the microscope will show that there has been an enormous increase in the number of the spherical and rod-shaped bodies. The fact that they have increased in number is an indication that they are living bodies. These small, living bodies are called *bacteria.*

It seems evident that the spoiling of the beef tea was associated with the development of bacteria within it. Many experiments have shown that the decay of plant and animal (organic) matter is always brought about by bacteria or their close relatives, the *molds.*

Problem 2. Where bacteria are found. — By the following experiments information may be obtained concerning the distribution of bacteria.

As in these experiments it is important to keep separate the descendants of different bacteria, a solid or semi-solid food material must be used. The food mixtures which we prepare to obtain a growth of bacteria, are called *culture media.* In the previous experiment the beef tea was a

liquid culture medium. A solid culture medium is made by adding to beef tea some agar-agar, a vegetable gelatine obtained from certain kinds of sea weeds. (Details of preparation are given in the appendix.) Into Petri dishes (flat dishes especially designed for study of bacteria) which have been highly heated to kill any living organisms present, pour some of this melted agar medium. Cover the dishes immediately. In a short time the culture medium will become jellylike and ready for use.

Experiment. — Expose open dishes in several of the following places for five minutes, then close and label: — a classroom, a corridor before the passing of classes, a corridor during passing of classes, a window sill outside of room, street, subway, park, etc.

Experiment. — By means of a needle, which has been heated (sterilized) to kill organisms upon it, put into dishes small amounts of material which you wish to test for the presence of microörganisms; *e.g.* dust from floor, saliva, dirt from under finger nails, milk, soil, etc.

Experiment. — Test various other substances, *e.g.* pupil's finger, breath, paper and silver money, drinking water, the edge of drinking cup, blade of a knife, pencil point, etc. Take care in every case that you prevent the entrance of any other material.

FIGURE 77. — COLONIES OF BACTERIA AND MOLD.

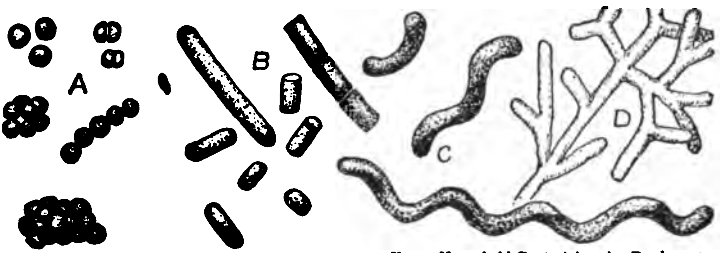
The agar culture medium in these dishes was exposed to the air for about 5 minutes.

Describe the results of these experiments. The spots which you see are colonies of bacteria or mold (Figure 77). Are there indications of the presence of more than one kind of microörganisms? Do you see any mold colonies? They are fluffy or hairy in appearance instead of waxy like the bacteria colonies. Does

there seem to be any connection between the presence of dust and the abundance of microörganisms?

Problem 3. Size, shape, and method of multiplication of bacteria. — Could you see the bacteria upon the agar plate when the plate was first exposed to the air? What does this indicate as to the size of the bacteria? You will find that they can be seen only with rather a high power of a compound microscope.

They are the smallest and simplest plant life known. The average rod-shaped bacterium measures about $\frac{1}{12500}$ of



From *Household Bacteriology* by Buchanan.

FIGURE 78. — THE FOUR TYPES OF BACTERIA.

A, cocci; *B*, bacilli; *C*, spirilla; *D*, branched filamentous organism.

an inch in length and about $\frac{1}{50000}$ of an inch in diameter. Some are larger and many are much smaller, some being so small that they are invisible under the highest power lenses, but known to be present because of the effect which they produce in the substance in which they are living. A calculation of the number in a cubic inch of average sized bacteria will give you some idea of the extreme smallness of these plants.

If you are fortunate enough to have a compound microscope for the use of your class you may observe the shape of the bacteria. If no microscope is available, examine

the drawings representing the different shapes. It will be noted that there are three principal forms of bacteria; spherical or ball-shaped (coccus), rod-shaped (bacillus), and spiral-shaped (spirillum) (Figure 78).

They multiply by dividing into two. These in turn, after growing to full size, will again divide. If conditions are favorable, bacteria may grow to full size and divide again in thirty minutes. It has been estimated that if bacterial multiplication went on unchecked and the division of each bacterium took place as often as once an hour, the descendants of each individual would in two days number 281,500,000,000. Actually, such unchecked multiplication never occurs except for a very short period, as conditions develop which interfere with further growth.

Not all microörganisms are bacteria. Yeasts and molds are rather closely related to the bacteria. There are also animals (protozoa) of approximately as simple structure as the bacteria. Some of these, because of the harm that they do, are of very great interest to us.

Since these extremely small living things cause our food to decay, it is important that we know the conditions which are favorable and conditions which are unfavorable for their growth, hence our next problem is:

Problem 4. What conditions are favorable and what unfavorable for growth of bacteria and molds? — This problem can best be solved by a number of experiments.

Experiment. — Take a number of test tubes, and into each pour about an inch of the beef tea culture medium to which has been added some material known to contain bacteria.

1. Stopper two tubes with cotton. Put one in a warm place, near a radiator or stove and the other in a cold place, as in the ice box.

2. Take two test tubes. Boil the contents of one. Stopper both tubes with cotton and keep both under the same conditions.

3. Into one of three test tubes put all the salt that will dissolve in the beef tea. Into the second put one half the quantity of salt placed in the first. Put nothing in the third.

4. Into one of three test tubes put an amount of sugar equal to the amount of beef tea. Into the second put one half this amount of sugar. Put nothing in the third.

After a few days, examine the various test tubes for bacteria. What is the apparent effect on bacteria of (1) warmth, (2) boiling, (3) salt, (4) sugar?

Experiment. — Expose to the air for ten minutes several Petri dishes containing agar culture medium. Paste over the covers black paper from which have been cut large letters for purposes of identification. Put the dishes where they will be exposed to sunlight. Examine after several weeks. Record the result.

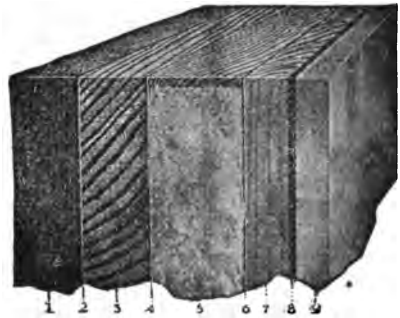
Experiment. — Expose to the air a Petri dish which has been kept until the culture medium has become dry.

The facts which we have learned from these experiments have many applications both in our home life and commercially. Some of these which most concern us in our everyday life should be considered.

Problem 5. Use of cold in the home in checking the growth of bacteria. (*a*) You at once think of the ice chest or refrigerator. Let us see if we can understand how the refrigerator is so effective in preserving our milk, meats, and vegetables. First, why is ice used in a refrigerator? You will at once say, because it is cold; but you know that a block of wood or stone or iron which might be just as cold is never used in place of ice. The reason for this use of ice may be illustrated by the following experiment.

Experiment. — Nearly fill two beaker glasses with water of the same temperature. Note the temperature. Place in one of the glasses a piece of ice and in the other a stone of equal size which has been kept

on ice and has the same temperature. Place the two glasses side by side and apply gradually an equal amount of heat. Note the temperature from time to time. Result? What effect does the melting of ice have upon the heat of the surrounding water? Is this not what you would expect? The removal of heat from water causes it to change into ice, so heat must be used up to change the ice back into water. Do you think that your refrigerator will be made colder by covering the ice with pads to keep it from melting?



Courtesy of McCray Refrigerator Co.

FIGURE 79. — WALL OF A REFRIGERATOR.

An ice chest or refrigerator is essentially a box whose walls are so constructed that they are poor conductors of heat (Figure 79). This is usually accomplished by having in the wall an air space which is packed with charcoal or some other poor conductor. The ice in a refrigerator should be placed near the top. The melting of the ice cools the air in contact with it. The cold air falls. (Why?) In so doing it forces the warm air to the top where it in turn is cooled and replaces the air which has been warmed by coming in contact with the food. The effectiveness of the refrigerator depends upon the circulation of air within it; and accordingly care should

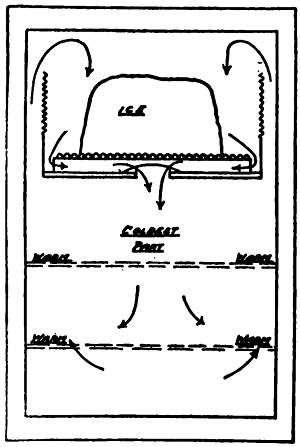


FIGURE 80. — CURRENTS OF AIR IN A REFRIGERATOR.

be taken that the free passage of air is not obstructed in any way (Figure 80).

The ice chest is simply a means of checking the development of bacteria but by no means does it stop their growth. In a large ice chest, food may be preserved for a considerable length of time but it finally will decay. In small ones, food may be kept for only a few days. All refrigerators should be frequently cleaned, as dirt and particles of food furnish a place for the growth of bacteria, and after a time render the refrigerator unfit for use.

FIGURE 81. — ICELESS REFRIGERATOR.

Various methods have been used in homes where ice cannot be obtained to provide a low temperature for the protection of food against the action of bacteria. Cool cellars, cold running water, spring houses, and suspension in deep wells are means frequently employed. An iceless refrigerator (Figure 81) may be made as follows:

Cover a frame of wood with cloth such as duck (Figure 82). Sew a number of lamp wicks to the edge of the cloth and allow the other end of the wicks to extend into a vessel of water on top of the frame. The water soaks into the cloth through the wicks. As heat is used up in evaporation

of water, the temperature within the refrigerator is lowered to 50–56 degrees F. The efficiency of this refrigerator is increased if it is kept where there is a current of air. Why? In tropical countries, drinking water is kept in porous earthenware jars. Why?

FIGURE 82. — FRAMEWORK OF AN ICELESS REFRIGERATOR.

Problem 6. Use of cold in storage warehouses. — In cold-storage plants low, constant temperatures are maintained. Definite temperatures are kept in different rooms, as not all foods are best preserved at the same temperature. Fruits are stored at a little above freezing; fresh meat, at about 25 degrees F.; poultry, at about 15 degrees F.; fish, at about 0 degrees F.

The question arises, How are these steady low temperatures produced? As ice is not used, a review of the principle of the iceless refrigerator may help us. (Explain the production of low temperature in the iceless refrigerator.)

Cold-storage plants generally use ammonia which has been changed into a liquid from a gas by pressure. When the pressure is released the ammonia returns to its gaseous

state, taking heat from everything around it (Figure 83). The effect of rapid evaporation (changing a liquid into a gas) may be illustrated by the following experiment.

Experiment. — Place some chloroform or ether in a thin watch crystal. Place the crystal upon a drop of water. Through a tube blow a current of air upon the chloroform or ether. As soon as it all has evaporated, notice the condition of the water. Result? Conclusion?

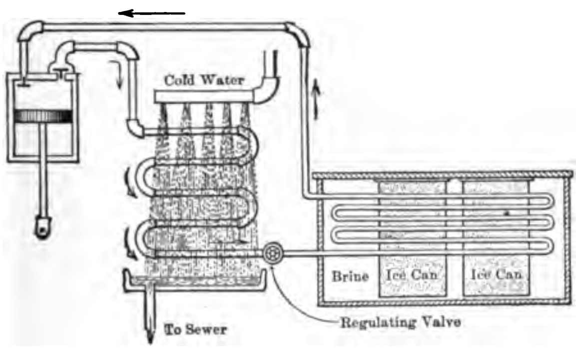


FIGURE 83. — ICE PLANT.

Ammonia which has been made liquid passes slowly through the regulating valve into pipes in which the pressure is very low. The ammonia quickly changes into a gas, absorbing heat in doing so from everything around it. The ammonia gas is removed by the pump at the left of the figure and is changed again by pressure and the spray of cold water into liquid ammonia.

The development of cold storage has been of great advantage both to producers and to consumers. Consider the condition which existed before the use of cold storage in the peach region of Michigan for example. Thousands of bushels of peaches ripened in a few weeks, with the result that the Chicago markets were swamped. Prices went down to almost nothing; but even then enormous quantities rotted. Sometimes the money received for the peaches was not sufficient to pay the transportation and brokerage

charges, and the fruit growers received nothing for their year's work. Did the people of Chicago profit by this condition? It is true that for a short time peaches could be bought for a very low price; the peach season was, however, made extremely short.

Since great storage plants have been built, conditions have changed entirely. Now, only enough fruit is put

FIGURE 84. — STORAGE OF BUTTER IN A REFRIGERATING PLANT.

upon the market to supply the normal demands; the surplus is put into cold storage warehouses to be taken out and sold as the supply direct from the orchards decreases. The producer now receives a fair return for his labor and investment. The consumer has a lengthened peach season and there is a minimum of waste.

It is now possible to have fresh at any season of the year the perishable foods produced at almost any other season.

Without cold storage the supply of such foods as butter and eggs and some other foods would be so limited at certain times of the year that they could be used only by the wealthiest people (Figure 84).

By means of cold-storage cars and ships, perishable foods may be transported almost any distance. American fresh meat is sold in the markets of London and Paris. Argentine beef is put on sale in American cities. Fruits of California and the southern states are delivered with little or no loss of flavor to every city in the country.

Problem 7. Use made of heat in food preservation. — A visit to a grocery store and observation of the rows of canned vegetables, fruits, and meats are sufficient to indicate the great use made of this method of preserving food. It is one of the chief agencies by which a regular and varied food supply is made possible. Without the modern methods of food preservation, cities such as New York, Philadelphia, and Chicago could not exist.

Experiment. — Open a can of meat of some kind, permit some of the contents to be exposed to the air for a day. Put portions of the meat into two test tubes. Place one test tube in boiling water for an hour. Stopper both test tubes with corks, dipping the stoppered ends into melted paraffin to make them air-tight. Put the test tubes aside in a warm place for a few days. Result? Conclusion?

Pasteurization of Milk. — As diseases may be transmitted by milk, the problem of destroying bacteria contained by it is of great importance. Tuberculosis, typhoid fever, scarlet fever, diphtheria, and very probably dysentery, are diseases spread by milk. The problem is rendered more difficult by the fact that boiling affects milk injuriously to some extent, causing it to become less digestible. It has been found that by heating milk to a temperature of 142

to 145 degrees F. for at least thirty minutes, the pathogenic (disease-producing) germs will be killed without injuring the digestible qualities of the milk. This process is known as *pasteurization*. Hospital records show, however, that it is advisable to give orange juice to children whose diet is almost exclusively pasteurized milk. Otherwise, rickets (a disease of the bones) or another disease known as scurvy may develop.

Problem 8. Use made of other methods of food preservation. — What methods for preserving food in addition to use of cold and extreme heat can you think of?

The use of sugar to preserve food may be shown by the following experiment.

Experiment. — Put some pieces of fruit into a test tube and cover loosely to prevent drying. Cover some similar pieces of fruit with melted sugar. Slightly heat the mixture of sugar and fruit, put into test tube and cover in the same way as the other tube was covered. Put both tubes aside in a warm place. Result? Conclusion?

Jellies and marmalades are examples of the use of sugar as a food preservative. From one of our experiments, what was your opinion as to the amount of sugar that should be used? If a smaller percentage is used, yeast will cause fermentation with resulting bubbles of gas and an odor of alcohol. Before canning became common, this method of preservation was much more used than at present. The large percentage of sugar causes some modification in the flavor of the food, and makes the material more of a sweetmeat than a fruit food. Condensed milk, which has come into such general use, remains unspoiled for a considerable time after the can has been opened because there has been added to it 30 to 40 per cent of sugar.

The use of salt as a food preservative is also very common.

Experiment. — Put small pieces of fresh fish into two test tubes. Cover the fish in one tube with brine (a saturated mixture of salt and water). Put aside in a warm place. Result? Conclusion?

Although salt preserves food from decay, the flavor of the material is considerably changed and it is usually less easily digested than when fresh. In many cases it is wise to soak the salty food in water before it is prepared for the table. Meats and fish are frequently preserved in brine. Eggs are also sometimes preserved in the same way. Salted butter can be kept fresh and of good flavor much longer than unsalted butter. Salt is used in connection with other methods of preservation such as drying and smoking.

Use of vinegar and spices. — Name foods that you know are preserved in vinegar. Sauerkraut is cabbage which has produced in itself, by the process of fermentation, an acid similar to that of vinegar, which protects it from further decomposition. Most of the spices used in the home have some antiseptic properties. Mince-meat is a good example of the ability of spices to prevent decay. In the same way, the spices in sausages not only give a desirable flavor but also prevent rapid spoiling. Spices, however, are only mildly antiseptic and are consequently of little value in this respect except when used in cold weather.

Drying and smoking are other methods of preserving foods.

Experiment. — Put some raisins which have been soaked in water for a day into a test tube. Into another test tube put some unsoaked raisins. Put aside in a warm place. Result? Conclusion?

Next to canning, drying is the most important method of preserving food. Compare flour which has been kept

dry with some which has been kept slightly moist for a week. In the same way compare bean and pea seeds and grains of corn and wheat which have been kept dry with the same kinds of seeds that have been soaked and permitted to remain moist. What is an advantage of hard-tack and crackers over bread? When fruits are completely dried, their flavor is largely lost. Those which contain a large percentage of sugar, such as grapes, prunes, peaches, figs, dates, currants, etc., may be preserved by the removal of only a limited portion of their water by drying. Why?

Meats are preserved on an immense scale by a combination of salting, drying, and smoking. Give examples. Milk is dried and put upon the market as a powder. When dissolved in water it has a flavor slightly different from that of fresh milk, but none of its nutritive properties has been lost. It possesses the advantages of occupying little space in transportation, and of being able to be kept indefinitely without decaying, souring, or molding. Evaporated milk has had a portion of its water removed, thus greatly reducing its bulk.

Briefly sum up the main points you have learned as to how to keep foods from spoiling, and why these methods are successful.

Suggested Individual Projects

1. Examination of bacteria with a microscope. Make drawings.
2. Making of agar culture medium.
3. Can a dozen jars of vegetables or fruit.
4. Construct a homemade device for pasteurizing milk.
5. Make six glasses of jelly.
6. Construct an apparatus for dehydration of vegetables. Dehydrate some vegetables that are difficult to keep through the winter. Cook and test.
7. Construction of an iceless refrigerator.

References for Project IX

1. Bacteria, Yeasts and Molds in the Home, W. H. Conn. Ginn & Co.

2. Household Bacteriology, E. D. Buchanan.

3. Milk and Its Products, H. H. Wing. Macmillan Company.

4. An Iceless Refrigerator. Food Thrift Series No. 4, U. S. Department of Agriculture.

5. Farmers' Bulletins, U. S. Department of Agriculture:
   - 375. Care of Food in the Home.
   - 521. Canning Tomatoes at Home and in Club Work.
   - 839. Canning by the Cold-Pack Method.
   - 841. Drying Fruits and Vegetables in the Home.

6. Circulars, U. S. Departm't of Agriculture, Canning, Evaporating.

7. Cold Pack Canning. International Harvester Company, Chicago.

PROJECT X

TO PROTECT OURSELVES AGAINST HARMFUL MICROÖRGANISMS

MICROÖRGANISMS can do many things beside causing foods to decay. Some do very valuable work; so valuable in fact, that without their aid life would cease to exist upon the earth. On the other hand, some, such as the disease-producing (pathogenic) forms, are extremely harmful, causing the premature death of many persons.

Fortunately the large majority of microörganisms are not pathogenic. If this were not true, we might well be appalled at the results of our experiments as to the distribution of bacteria. Most of the bacteria discovered in those experiments are capable of producing decay only, but it must not be forgotten that the objects and substances examined, while they are often carriers of non-pathogenic bacteria alone, still may frequently be carriers of disease-producing ones.

In considering how to protect ourselves from harmful microörg nisms, we must consider how they affect us, how the microörganisms (germs) may be carried from one person to another, how the body naturally fights the germs, how the body may be given special power to fight them, and finally how certain substances called *disinfectants* and *antiseptics* may be used to destroy germs.

Problem I. How bacteria and other microörganisms affect the health. — What frequently happens when you get a

splinter in your finger? It has been found that if the splinter was free from bacteria no irritation resulted. What is your conclusion? The red, swollen, and painful condition (inflammation) is now known to be due to poisons or *toxins* which are produced by certain bacteria which were on the splinter.

Usually after a short time the inflammation vanishes, and a small amount of pus appears which should be removed

FIGURE 85. — DEAD CHESTNUT TREES.

These trees along a road in New York State were killed by the chestnut bark disease.

with a needle which has been passed through a flame and the broken place in the skin washed with an antiseptic, a substance that kills or checks the growth of bacteria. The pus is produced by the action of white blood corpuscles which have attacked and destroyed the bacteria. Sometimes, however, the bacteria are not destroyed and the in-

flammation may spread and possibly finally develop into blood poisoning.

The inflammation of pimples and boils is also caused by bacteria, and the pus is formed in the same way.

You have all noticed that if one member of a family gets a cold frequently the other members also contract it. Microscopic examinations have shown that bacteria of certain kinds are always associated with colds. It is very evident that this inflammation, as in other cases of inflammation, is due to the production of poisons or toxins by the bacteria.

In the case of colds a congestion of blood in some organ as in the lining of the nose, throat, or intestine offers a favorable condition for the development of bacteria. Prevention of unusual chilling of any part of the body will assist in the avoidance of colds, as congestion of blood will then be prevented. It is especially important to avoid chilling the body when one is fatigued or tired, as then there is greater susceptibility to disease. Regular and sufficient muscular exercise, avoidance of overeating, and good habits of sleep and rest are other conditions that enable the body to resist the bacteria which cause colds.

Microscopic examination has shown that the decay of teeth and diseased conditions of the tonsils are due to the growth of bacteria. The seriousness of the growth of bacteria in decayed teeth and in the tonsils is only beginning to be realized. The bacteria or the poisons produced by them may be carried by the circulatory system to other organs and there cause serious diseases. Certain forms of rheumatism, mental diseases, digestive troubles, etc., are cured by getting rid of these breeding places for bacteria. The teeth are also liable to a disease known as Riggs' disease,

or pyorrhea, which consists in the formation of an abscess or pus cavity between the roots and the jaw bone, causing the teeth to loosen and in some cases to fall out. This disease is not caused by bacteria, which are microscopic plants, but by simple animals called *amœbæ.*

With very few exceptions diseases are produced by microörganisms, chiefly bacteria. Since the microorganisms (germs) which cause these diseases may be transferred in various ways from one person to another, the diseases are called *communicable.* The better known diseases of this kind are: tuberculosis, typhoid fever, influenza, diphtheria, scarlet fever, measles, chicken-pox, summer complaint of children, dysentery, smallpox, lockjaw, mumps, Asiatic cholera, infantile paralysis, malaria, yellow fever, etc. In a few of the diseases mentioned above, the germ which is believed to cause the disease has not been seen with the microscope, but the way in which those diseases develop and are transmitted indicates that they are caused by living germs.

Problem 2. How disease germs may pass from one person to another. — Naturally in considering this problem for any disease, we must consider how the germs le ve the body of the person having the disease and how they may get into the body of the well person. Germs usually leave the body in the fine particles of moisture given out in sneezing or coughing or in the sputum or other excretions of the body, and occasionally by blood sucked up by insects. Suggest ways by which disease germs may gain entrance to the body.

The problem will be considered from the standpoint of a few of the most common diseases.

Tuberculosis or consumption. — The most usual form of this disease is tuberculosis of the lungs. How do you think the germs may reach the outside of the body? A well person may contract the disease by breathing in the germs or in some way getting them into his mouth. Make a list of the ways in which the germs of this disease might pass from a sick person to a well person.

It has been found that the principal ways in which the germs of this disease are carried from one person to another are: (1) by personal contact of sick with well person, especially by kissing; (2) by objects handled or put into the mouth, as by food, forks, drinking cups, pencils, or towels; (3) by fine droplets given off in coughing or while talking (this is probably one of the most common methods); (4) by dust containing dried sputum; (5) by milk or meat of tuberculous animals.

Typhoid fever. — In a person sick with this disease the germs are developing in the walls of the intestine. How do you think the germs escape from the body? How do you think that they may ever reach the intestine of a well person to begin growing there to produce the poisons of the disease?

Typhoid fever germs are taken into the body with food and drink. It hardly seems possible that anyone should ever contract typhoid fever when we realize that the germs leave the diseased person in the excretions of the body. However, food and drink may become polluted in a number of ways. Water may become contaminated by sewage; milk, by the unclean hands of milkers; oysters or clams, by growing near the outlet of sewers; vegetables, by manure; fruits and berries, by filthy hands; foods of all kinds, by flies which have been crawling over the excretions of a typhoid patient.

Suggest means to be taken to prevent the spread of typhoid germs.

Unfortunately, persons who are immune to the disease may yet have the germs produced in their bodies, and be unconscious sources of infection. Thus we sometimes read of such carriers of germs as "Typhoid Mary" of New York City who, though perfectly well themselves, are a greater menace to the public than persons who are ill with the disease.

Other diseases may be transmitted in some of the ways in which tuberculosis and typhoid fever are transmitted, while some are carried by somewhat different methods. Diphtheria is a disease of the throat. Suggest how it might be transmitted, and how its spread may be prevented. The germ that is supposed to cause influenza is found in the secretions of the mouth and nose of patients. Suggest means by which it may be spread.

Tetanus or lockjaw is produced by germs which are common in soil. They will not develop in man unless injected into the body along with considerable dirt in a wound that closes up and prevents the access of air. Wounds caused by rusty nails and toy pistol explosions are especially favorable for the development of tetanus. How should a wound of this kind be treated to prevent the development of tetanus?

The germs of pneumonia are present in the lungs and air passages. Suggest possible means of infection. Malaria germs are carried from one person to another by a certain kind of mosquito which lives near swamps and flies only at night. How can one protect himself from this disease?

Problem 3. How the body fights disease. — Considering the ease with which disease germs may enter the body, it

may seem strange that a person is not constantly ill with some disease. We know, however, that not every person exposed to infection contracts the disease. There are a number of reasons for this.

What is the effect of the unbroken skin? What happens to large amounts of dirt and dust of the air which is breathed in through the nose? What is the appearance of the mucus which is blown out of the nose after you have been working in a very dusty place? Not only does the mucus catch some of the germs that are breathed in and permit their removal but it has been found that it possesses some power to kill the germs. Suggest one reason for breathing through the nose rather than through the mouth.

Even though these outer defenses of the body are passed, the germs are not permitted to develop unchecked. The body offers a certain resistance to the attacks, partially by means of the white blood corpuscles which engulf the bacteria, and partially by the resistant power of the blood and living parts of the body, a power which is not so easily understood.

This power of resistance is affected by a number of things. The fact that certain diseases occur only in childhood indicates that age is one of the factors concerned. A poor diet, excessive fatigue, extremes of heat and cold, lack of sleep, lack of fresh air, and weakness from other diseases are conditions which lessen the power of the body to resist disease. In general, any condition which increases the health of the body increases its power to resist disease. Because of this fact, outdoor life, deep breathing, moderate exercise taken regularly, a proper amount of sleep, and good food are not only the preventives of disease but in some cases constitute a cure by giving the body a chance to

fight off the enemy that has already gained a foothold (Figure 86).

Problem 4. How the body acquires special power to fight disease. — You already have some information that proves to you that special ability to fight disease may be acquired by the body. A child has had whooping cough, or mumps, or measles. Does this have any effect upon his

FIGURE 86. — A FRESH AIR CAMP IN CALIFORNIA.

chance of taking the disease again? What, therefore, is your conclusion as to the effect of having had a disease upon the ability of the body to fight that disease?

Based upon this fact, it has been discovered that the body may be made immune to certain diseases or protected against them. You know of a number of such cases. Why is smallpox not the common disease it was several hundred years ago? How are the soldiers protected against typhoid

fever? Why is diphtheria not the dreaded disease it was twenty-five years ago?

The most striking cases of acquired immunity are for smallpox, typhoid fever, diphtheria, hydrophobia or rabies, and anthrax, a disease of animals. Efforts are being made to develop acquired immunity from other diseases, and considerable success has been obtained in the treatment of tetanus or lockjaw, boils and carbuncles, meningitis and plague.

(a) *Vaccination against smallpox.* — Over a hundred years ago, Edward Jenner, an English physician, observed that dairymaids were not subject to smallpox, which at that time was a very common disease. His experiments based on this observation have led to the practice of vaccination to develop immunity from smallpox. Cattle may have a disease known as *cowpox,* during which small sores appear on the animals. These sores contain the germs of the disease. Jenner found that by scratching the arm of a person and rubbing into the slight wound some material from these sores on cattle, a mild disease, cowpox, was developed in the person thus vaccinated. During the process of the disease, something evidently developed in the blood which protected the person from smallpox.

Since vaccination has been practiced, smallpox, previously one of the most common diseases, has become a very rare one, developing only when vaccination is neglected. Stricter regulations by boards of health, especially in regard to isolation of patients, has helped materially in bringing about this result. Formerly, when not so great care was taken as now to insure the purity of the vaccine, infection occasionally occurred from other germs introduced into the wound. This has now been obviated, and anyone who objects to vaccina-

tion is unwilling to perform his part as a good citizen to maintain the health of the community.

(b) *Vaccination against typhoid fever.* — Vaccination in this case is performed by injecting into the body a large number of dead typhoid fever bacteria. Usually three injections are given at intervals of several days. Typhoid fever up to recent times has been the special scourge of army camps. The value of anti-typhoid vaccination may be appreciated if we compare the prevalence of the disease in the army before and after vaccination was practiced.

In the Franco-Prussian War, 60 per cent of the total German mortality was due to this disease. In the Spanish-American War the army of the United States consisting of 107,973 men had 20,738 cases of typhoid fever and 1580 deaths from the disease. During the summer of 1911, after the adoption of anti-typhoid vaccination by our government, an army division of over 12,000 men was encamped at San Antonio, Texas, for about four months. Among these men only one case of typhoid fever developed and that was of a soldier who had not completed the necessary inoculation. In the armies of the Great War, typhoid fever was an almost unknown disease.

(c) *Immunity from diphtheria.* — The antitoxin which has curative as well as immunizing power against diphtheria is made in the following manner. The bacteria are permitted to develop in a culture medium until a considerable quantity of toxin, or the poison produced by the germ, is present. After all the living germs have been killed, a small amount of the toxin is injected into a healthy horse. The toxin evidently stimulates the blood of the horse to manufacture something called antitoxin which counteracts the poison so that the later injection of toxin may be greater in amount

without injury to the horse. This process is continued until the amount of toxin injected into the horse is several hundred times as much as would have killed it at the beginning.

A certain amount of the blood which contains great quantities of antitoxin is now removed from a large vein in the neck of the horse. (All this is done without pain or injury to the animal.) The serum which separates from the blood when it clots contains the antitoxin. This serum

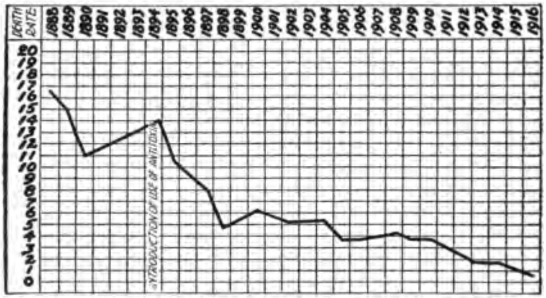


FIGURE 87. — RESULTS OF USE OF DIPHTHERIA ANTITOXIN.
Chart showing death rate per 10,000 from diphtheria before and after the introduction of antitoxin.

is tested for the amount of antitoxin it contains, is sterilized, and put into vials ready for use by physicians.

The accompanying chart shows the effect of the use of antitoxin upon the death rate from diphtheria in New York City (Figure 87).

Antitoxin is of greater use as a curative than as an immunizing agent. Persons who have been exposed to diphtheria will be protected only from two to six weeks, but this is usually long enough to protect the members of a family in which there is a case of the disease. As a cure for diphtheria, it is most important that the antitoxin be given

at a very early stage of the disease. The importance of this is shown by Figure 88.

(*d*) *Pasteur treatment for hydrophobia or rabies.* — This disease especially affects the nervous system. Pasteur, a noted French scientist, found that while the spinal cord of a rabbit having the disease contains a large amount of the poison of the disease, the virulence or power of the poison decreases if the spinal cord is removed from the rabbit and allowed to dry. As the disease does not develop for some time after a person is bitten by a mad dog, there is sufficient time for treatment. The treatment consists in the injection of material from a rabbit's spinal cord which has been permitted to dry until the poison has almost entirely disappeared. This is followed by injections, more and more virulent, of spinal cord material for a period of about three weeks. In thousands of cases which have been treated by this method there has been a mortality of less than one per cent. Just as in the case of the use of antitoxin for treatment of diphtheria, this treatment should be begun at the earliest possible time after infection has occurred.

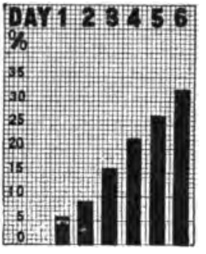


FIGURE 38. — DANGER OF DELAY IN USING ANTITOXIN.

Numbers at the left indicate the percentage of the cases that result in death.

Problem 5. Use of disinfectants and antiseptics. — Certain substances are used to prevent the growth of bacteria. Make a list of substances that you know are used for this purpose.

The way in which they affect the growth of bacteria may be found out by the following experiment.

Experiment. — Into each of several test tubes pour about 10 cc. of unsterilized beef tea culture medium.

To one add 3 cc. of carbolic acid 5% solution.

To another add 3 cc. saturated solution of boracic (boric) acid.

To another add 3 cc. 1–1000 solution of mercury bichloride.

To another add 3 cc. hydrogen peroxide.

To another add 3 cc. tincture of iodine.

To another add 3 cc. formaldehyde, 4%.

To the others add 3 cc. different disinfectants.

To one add nothing.

After four or five days examine all the test tubes and record the results.

A distinction is usually made between antiseptics and disinfectants. An antiseptic is a substance that will check or retard the growth of bacteria, but does not destroy them. A disinfectant, or germicide, is a substance that kills bacteria. Some substances may be classed under both heads; a strong solution of it acting as a disinfectant, a weak solution acting only as an antiseptic. Salt, sugar, spices, and vinegar may be considered antiseptics that are harmless when taken into the body with food. With the exception of the use of one tenth of one per cent of benzoate of soda, other antiseptics are not permitted to be used for the preservation of food.

The more important germicides are tincture of iodine; carbolic acid (5 to 10 per cent solution); mercury bichloride (1 part to 1000 or 1500 parts of water); chloride of lime, and formaldehyde. These are all highly poisonous when swallowed, and great care should be taken that they are not placed where they may accidentally be used in this way.

Boracic acid is a mild antiseptic which is frequently used as an eye or mouth wash. Hydrogen dioxide (peroxide), when it has not been allowed to remain exposed to the air, will destroy germs. It has the advantage of being non-poisonous,

but it has the disadvantage of losing its value if kept in a bottle which is not well corked.

Suggested Individual Projects

1. Proof that flies may carry bacteria.
2. Demonstration of the comparative value of the use of a feather duster and an oiled cloth in dusting, and of a broom and a vacuum cleaner in sweeping.

Reports

1. Work of boards of health.
2. Dangers from decayed teeth.
3. Transmission of various diseases.
4. Difference between the ordinary mosquito and the malaria-carrying mosquito.
5. Description of operations that have been carried on to get rid of malaria-carrying mosquitoes.
6. Description of experiments to prove that malaria is carried by mosquitoes.
7. Account of experiments to prove that yellow fever is carried by mosquitoes.
8. The fight against tuberculosis.
9. The history of the discovery of vaccination against smallpox.
10. Discovery and value of diphtheria antitoxin.
11. Vaccination against typhoid fever and its importance.
12. Pasteur and his discovery of the treatment for hydrophobia.
13. Transmission and seriousness of hook-worm disease.

References for Project X

1. Primer of Sanitation, John W. Ritchie. World Book Company.
2. Preventable Diseases, Woods Hutchinson. Houghton Mifflin Company.
3. How to Live, Fisher and Fisk. Funk and Wagnalls.
4. Town and City, Frances Gulick Jewett. Ginn & Co.
5. A Home-made Fly Trap, International Harvester Company, Chicago.
6. The Human Mechanism, Hough and Sedgwick. Ginn & Co.
7. House Flies, Farmers' Bulletins 459 and 851. U. S. Department of Agriculture.

PROJECT XI

TO FIND OUT HOW SOME BACTERIA AND MOLDS ARE USEFUL

WE have found that bacteria and molds are a great nuisance, bringing about a waste of food material and leading us into the expenditure of time and money to prevent their ravages. We have found also that almost all diseases are caused by them. Just think of how conditions would be changed if there were no such little plants. Foods would not spoil, and diseases like tuberculosis, typhoid fever, influenza, etc., would be unknown. It would seem, therefore, that the world might be a better place in which to live if bacteria and molds ceased to exist. But before we come to this conclusion it will be well for us to consider if there is any evidence that bacteria and molds are of value.

Problem 1. Are bacteria of decay of any value? — A consideration of the following facts may help us to solve this problem. Just as plants take carbon dioxide from the air and build it up into starch, so they also take simple substances from the soil and build them up into complete plant materials. This means the removal from the soil every year by plants of an immense amount of these simple substances needed by plants. Since the amount of these substances is limited, what must happen soon unless in some way they are returned to the soil?

This return is brought about by the action of bacteria in causing complex plant and animal materials (organic mat-

ter) to decay. By decay the organic matter is changed back into the simple substances which plants use in growth. Thus it may be understood that the same matter may many times alternately be built up into plant and animal material and again be reduced to a simple condition.

This building up and tearing down may be illustrated very simply by considering the use of building blocks by a child. Suppose a child has two hundred blocks, and builds them up into a house, then tears it down and builds another structure. This he may do time after time, using the same blocks over and over again in perhaps a different construction each time. Plants build up. Bacteria of decay tear down. Just as the child builds up and tears down his block houses many times, so these processes of building up by plants and tearing down by bacteria will go on as long as life exists upon the earth. What then do you think would be the condition of the earth in a few years if there were no bacteria and molds to do this tearing down?

Problem 2. How bacteria on the roots of some plants may enrich the soil. — Farmers have known for a long time that a crop of clover will improve the soil. But the reason for this has been known for only relatively a few years. It was found that in some fields clover plants did not have the power to improve the soil. A comparison of the plants showed that those which possessed this power all had little enlargements (called *nodules*) on their roots (Figure 89).

It was found also that if some of the soil from the field containing nodule-bearing clover plants was scattered over the other field, the clover plants in this field also developed nodules on their roots and gained the power to improve the soil. An examination of these nodules led

to the discovery that they contained bacteria. It was found then that the soil could be inoculated with a culture of these bacteria either by mixing it with the clover seed before it was planted or by adding it directly to the soil.

It has been found that the bacteria in these nodules have the power of changing the nitrogen of the air, which cannot be used directly by plants, into a form which may be built up into the living matter of the plant. All of the plants of the clover family (legumes) may have these nodules containing nitrogen-fixing bacteria. Some of the principal members of the family are peas, beans, vetches, and alfalfa. If the soil does not contain the proper kind of bacteria, the nodules will not be formed and these plants will not be able to add to the fertility of the soil.

FIGURE 89. — ROOTS OF A BEAN PLANT.
The enlargements are nodules containing nitrogen-fixing bacteria.

There are other bacteria in the soil, not associated di-

rectly with plants as these nodule-inhabiting bacteria are, and these other bacteria have the power, under certain favorable conditions, of making the nitrogen of the air usable by plants.

Problem 3. How bacteria are useful in other ways. — Butter made from sweet cream lacks the pleasant taste of sour cream butter. This is because in the ripening of cream bacteria have been growing in it, and these produce the flavor which we enjoy in butter. That the especial bacteria which produce the desirable taste may be present, the cream may be inoculated with a pure culture or a starter, such as a small quantity of cream known to have developed the desired flavor. Frequently the desirable kinds of bacteria become domesticated in a dairy and good butter is produced without any effort on the part of the butter maker to bring about their introduction.

Likewise the flavor of cheese is produced by bacteria or molds, the different flavors being produced by different kinds of organisms. The ripening of cheese is a much more complicated process than the ripening of butter, since it depends upon the successive activity of different groups of bacteria or molds as well as upon the presence at the right time of suitable aroma-producing species. The holes in certain cheeses are produced by gas formed as a result of the action of particular bacteria.

The action of bacteria is important in the tanning of skins for the production of leather; in the curing of tobacco; in the process of obtaining linen fiber from flax; and in the manufacture of vinegar. The "mother" of vinegar with which most of us are familiar is made up of a great mass of bacteria which have the power to change the alco-

hol of the wine or cider into the vinegar acid (acetic acid). The action of these vinegar-forming bacteria is hastened by free access of air, so that barrels containing cider to be changed into vinegar should be only partially filled and an opening should be left in the top of the barrel to admit air. The formation of vinegar may be hastened by permitting the cider to trickle through casks filled with shavings impregnated with old vinegar. Why?

Suggested Individual Projects

1. Grow clover seed in soil which has been baked and moistened with boiled water, and in ordinary garden soil.
2. Collection of different roots showing nodules.
3. Manufacture of vinegar from cider.

Reports

1. Practical use made of nitrogen-fixing bacteria.
2. Importance of bacteria in manufacture of dairy products.

UNIT II

RELATION OF WATER TO EVERYDAY ACTIVITIES

PROJECT XII

MOISTURE IN THE AIR AND ITS IMPORTANCE TO US

A NUMBER of problems immediately occur to us: how dew, fogs, clouds, and rain are caused; why some parts of the earth receive a much larger rainfall than other parts; how water may be supplied to regions of very little rainfall; how moisture gets into the air, and the effect of moisture in the air (humidity) upon our comfort.

Problem 1. How dew is caused. — We all have had the experience of getting our feet wet by walking in the grass early on a summer morning. This moisture upon the grass is called *dew*. What are some of the things that you know about dew? Was it on the grass during the day before? About what time did it begin to appear in the evening? Have you ever seen it on anything except grass? Does it seem to form to the same extent on all objects? If possible give examples. Does dew form on objects in the house? On the porch? Is there approximately the same amount of dew every morning? Does wind seem to make any difference? Does it make any difference whether the night is clear or cloudy? Have you ever noticed moisture similar to dew on water pipes or on a glass filled with cold water?

The questions above are for the purpose of bringing to attention the facts that you know about dew. Do not guess at the answers, as that would destroy the value of the questions.

Several simple experiments will enable us to understand something about how dew is formed, and under what conditions.

Experiment. — Take two large test tubes or drinking glasses. Into one of these pour some ice water; into the other pour water at the room temperature. Set side by side and note results.

Experiment. — Into one of two wide-mouthed jars pour a small quantity of water. Place the two jars on a radiator or heat slightly with a Bunsen burner. Suspend for a few minutes in each jar a test tube containing ice water. Note results.

After considering these two experiments, what do you conclude are the two conditions necessary for the formation of a film of water like dew upon objects?

Experiment. — Pour a few drops of water into a test tube. Heat the test tube until the water disappears. Now partially immerse the test tube in a jar of ice water. What is the result? What do you conclude to be the relation between the temperature of the air and its ability to hold water in the form of vapor, or gas?

The temperature at which moisture in the air changes from an invisible vapor to visible drops of water, is called the *dew point*. Is the dew point temperature always the same? Why? Why is it possible to "see your breath" on a cold day?

We are now able to arrive at the explanation of the conditions under which dew is formed.

(*a*) Objects on the earth cool off after the sun sets. What effect does this have upon the surrounding air? What may result?

(*b*) Some objects give off their heat more readily than others, as for example, a hatchet left outdoors during the night may have a very large amount of dew on the metal part, and but little on the wooden handle. Suggest other examples that you have observed.

(*c*) Clouds act like a blanket over the earth, preventing

Photographed by A. J. Weed.

FIGURE 90. — ALTO-CUMULUS CLOUDS.

the heat from escaping. What effect will this have on the formation of dew?

(*d*) The layer of air next to the cool object is cooled down to its dew point. Why will wind prevent the formation of dew?

(*e*) Since the dew point is affected by the amount of moisture in the air, what is the effect of dry weather on the formation of dew?

(*f*) What is the result when the dew point is at the temperature of freezing or below?

Explain the following:

(1) The appearance of steam from an exhaust pipe or a steam whistle, and its appearance when it is a little farther away from the vent. Where does it go? Hold a Bunsen

Photographed by A. J. Henry.

FIGURE 91. — UNDULATED ALTO-CUMULUS CLOUDS.

burner or a candle near the "visible steam" escaping from a vessel, such as a tea-kettle. Result?

(2) The mist produced by blowing one's breath on a mirror or window glass.

(3) Why growing plants may be protected from frost by placing canvas or sheets of paper over them.

(4) Why the fruit grower sometimes makes a smudge (smoke) in the orchard when frost threatens.

(5) Why gardens in the valleys are more likely to be

affected by early frosts in the autumn than gardens on hillsides.

(6) Why the farmer is much more afraid of frost on a clear night than on a cloudy one.

(7) Why he is more afraid of frost on a quiet night than on a windy one.

Problem 2. How fogs and clouds are produced. — (1) Explain the formation of the thin layer of mist which

FIGURE 92. — CUMULUS CLOUDS OVER PACIFIC OCEAN.
Point Loma, San Diego, California, late afternoon.

is sometimes seen spread over a swamp or valley bottom. Why does it disappear as soon as the sun begins to shine?

(2) Fogs are common on the Banks of Newfoundland and the coast of Maine whenever the wind is from the south. Farther south, as far as Cape Hatteras, fogs are apt to occur when the wind is from the east. Why? (Re-

view your geography as to the relative locations of the Gulf Stream and the Labrador Current.)

(3) Suggest an explanation of the great fogs which are so common in the British Isles. (Note that bodies of land cool more rapidly than large bodies of water.) At what time of the year do you think fogs would be most common in England? In all cases the presence in the air of small particles of dust encourages the formation of fog. Why? This, no doubt, has considerable effect in intensifying fogs over cities such as London.

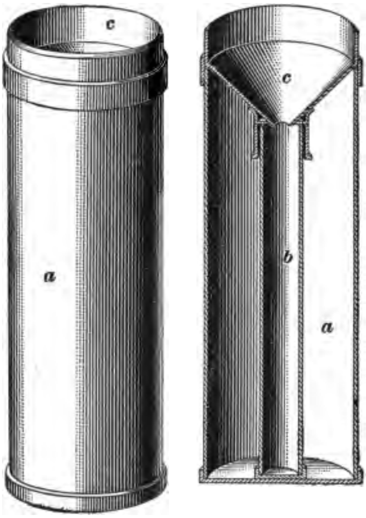


FIGURE 93. — RAIN GAUGE.

The area of the top of the outer cylinder (a) is exactly ten times as great as that of the inner cylinder (b); c, receiver.

Clouds are made up of a collection of small particles of water, floating some distance above the earth. Suggest how the great masses of clouds with horizontal bases, seen on a summer day, have been formed (Figure 92). Refer back to your study of weather and explain why clouds are present in a low pressure area and not present in a high pressure area.

Problem 3. How rain, snow, and hail are formed. — In a cloud or a fog the water particles are so small that they will remain suspended in the air for a long time. The small globules of water in a cloud are either prevented from fall-

ing below the base of the cloud by upward currents of air, or by passing into a part of the air where the conditions of temperature and moisture are such that the globules of water will be changed back into invisible water vapor.

As the amount of water, however, in a cloud increases by the changing of a greater quantity of vapor into globules of water (condensation), the small globules combine to form

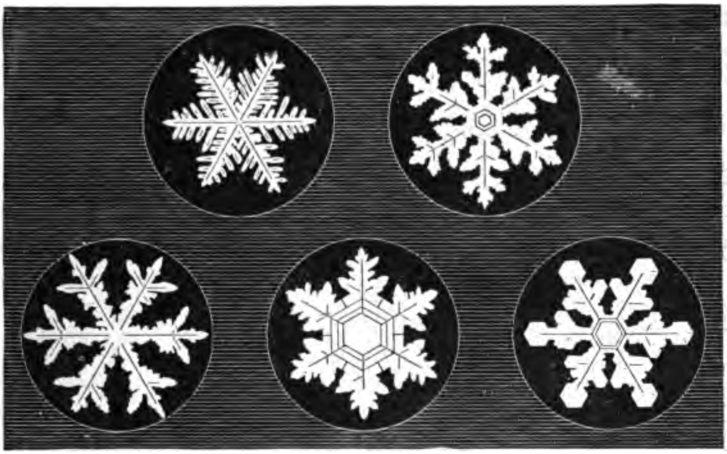


FIGURE 94. — SNOWFLAKES (enlarged many times).

drops of water which fall to the earth as rain. The change from small globules to large drops may be illustrated by the following experiment:

Experiment. — Cover with a metal lid a large beaker glass containing about an inch of water. Gradually heat the beaker glass with a Bunsen burner. Note results.

If the temperature of the air at the time of condensation is below the freezing point, the moisture crystallizes into snowflakes (Figure 94). If raindrops are frozen into little

balls in their passage through the air, they become hailstones. Hail is usually formed in summer, and is probably caused by currents of air carrying the raindrops to such a height that they are frozen and sometimes have formed on them a layer of snow. Split hailstones will frequently show several layers of ice and snow, indicating that they have been carried up a number of times before finally falling to the earth.

FIGURE 95. — HEAVY FALL OF SNOW IN A PINE FOREST.

Problem 4. Reasons for unequal distribution of rainfall. — A study of the average annual rainfall map of the United States (Figure 96) shows that the distribution of rainfall is very unequal, varying from 80 to 100 inches per year in a narrow strip along the ocean in Washington and Oregon to less than 5 inches per year in portions of Nevada, southern California, and Arizona (Figure 97).

FIGURE 96.

With maps before you of the topography of the country and the prevailing winds, explain the following:

(1) The great rainfall of the northwest coast of the United States. What is the prevailing wind? (Air cools as it rises along the side of a mountain.) Why is this rainfall belt so narrow?

FIGURE 97. — LANDSCAPE IN AN ALMOST RAINLESS DISTRICT IN ARIZONA.

(2) The small rainfall of the great region just east of this coast area.

(3) The sources of rainfall of the Mississippi Valley and region east of it to the Atlantic Coast.

(4) In middle and southern California, the prevailing wind from December to May is from the ocean, while during the remainder of the year it is from the land toward the ocean. Explain the dry and rainy seasons of this region.

Problem 5. How water is supplied to dry areas. — Portions of the country, which were unfit for agriculture because of too little rainfall, have been changed into good farming regions by irrigation (Figures 98 and 99); water from the mountains being collected in large reservoirs and carried by flumes, pipes, or cemented ditches, for great distances, to where the water is needed (Figure 100).

The accompanying map shows the location of districts irrigated as a result of the work of the United States Reclamation Service (Figure 101).

FIGURE 98. — ARIZONA DESERT BEFORE IRRIGATION.

FIGURE 99. — ARIZONA DESERT AFTER IRRIGATION.

Problem 6. How moisture gets into the air. — *Evaporation.* — It is evident that there must be considerable water in the air, in the form of invisible vapor. It has been estimated that if all the moisture in the air were condensed into water, it would make a layer of about one inch in depth over the entire surface of the earth. Some

FIGURE 100. — ROOSEVELT DAM, ARIZONA.
A large dam for collection of water for irrigation.

very common observations will indicate to us how this water gets into the air.

(1) What happens to wet clothes hung in the air?

(2) On what kind of days do they dry best?

(3) Do they dry better during day or night?

(4) What becomes of the rain puddles that are formed on the streets? Does the temperature seem to make any difference?

(5) What happens to a shallow pan of water left standing for a number of days?

FIGURE 101.—MAP SHOWING LOCATION OF IRRIGATION PROJECTS.

(6) What must be added to a balanced aquarium from time to time?

(7) Will frozen clothes, hanging on a line, dry?

(8) What happens to water that falls on soil, as in a cultivated garden or field?

(9) After a number of dry days, compare the moisture of soil under a board or stone with that of the surrounding soil. During very dry weather in summer, almost the only place one can find earthworms is under boards, logs, or stones. How do you explain this?

(10) When barrels are left empty they often fall to pieces. Why?

(11) In dry weather, farmers sometimes pour water around the rims of the wheels of their wagons. Why?

(12) How do leaves appear after having been removed from a plant?

From these observations we must conclude that objects containing water give it off to the air. The changing of the water into a vapor is called *evaporation*, the reverse of condensation which we considered in the formation of dew, clouds, and rain. From your observations, state the conditions which you think would affect the rapidity of evaporation. Not only are objects on the land giving off water in the form of vapor, but also the surfaces of all bodies of water, — rivers, lakes, and oceans. This water, in an invisible form as vapor, is changed back into visible forms as dew, clouds, rain, and snow.

When water evaporates, substances dissolved in the water remain behind. This may be illustrated by allowing a vessel of water in which has been dissolved some soda or salt to stand exposed to the air until the water has evaporated. Water in streams flowing to the ocean contains some soluble mineral material taken from the earth, through which the water has trickled. What happens to this mineral material when the water evaporates (Fig-

FIGURE 102. — RUSSIAN SALT FIELDS.
Salt is left after evaporation of water.

ure 102)? State in your own language, what you consider to be the cause of the saltness of the ocean. Endeavor to find out why the Great Salt Lake contains salt water, and the Great Lakes, fresh water.

Problem 7. How the amount of moisture in the air affects our comfort. — The effect of the amount of moisture in the air (humidity) upon our bodily comfort has been discussed under ventilation. It is the relative humidity rather than the actual humidity that affects us. The *relative humidity* is the ratio of the amount of water in the air to the amount which it can hold at a given temperature. A relative humidity of 50% means that the air contains one half of the amount of moisture that it can hold at that temperature.

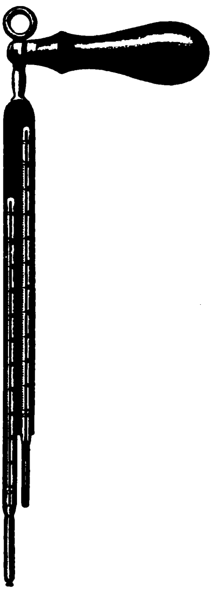


FIGURE 103. — WET AND DRY BULB THERMOMETER.

You will recall that damp days either in summer or winter are more uncomfortable than dry days of the same temperature. To understand this, we must consider how heat is lost from the body in winter and summer. What is the chief means of loss of heat from the body in winter? Explain the feeling of chill experienced on a damp day in winter, keeping in mind that moist air is a better conductor of heat than dry air. What is the principal way in which heat is lost from the body in summer? Explain now why we are more oppressed by the heat on a damp day.

The relative humidity of the air may be found by using the wet and dry bulb thermometer or psychrometer (Figure 103). This consists of two thermometers, one of which has a piece of wet muslin around its bulb. These are rapidly whirled in the air. Observations of the readings of the thermometers immediately after the muslin has become dry will

show considerable difference. Explain. Tables have been prepared which give the relative humidity of the air corresponding to the difference between the dry bulb and the wet bulb thermometers at the different degrees of temperature.

Another instrument for measuring the relative humidity of the air is the hair hygrometer. The human hair, when the oil has been removed, shortens with dampness and lengthens with drying. A hair prepared in this way is attached to a pointer which is moved across a dial as the hair changes in length.

Use is made of the fact that paper or cloth impregnated with certain chemicals will change color as the relative humidity becomes greater or less. A paper flower, for example, which has been soaked in a solution of cobalt chloride and gelatine, will be violet in color when the relative humidity is high and blue when the air is dry.

Reports

1. How railroads fight snow.
2. Origin of borax and other salt deposits in the West.
3. The salt supply of the United States.

References for Project XII

1. Measurements for the Household, Bureau of Standards, Washington, D. C.

2. Humidity; Its Effect on Our Health and Comfort, P. R. Jameson. Taylor Instrument Company, Rochester, N. Y. 10 cents.

3. The Mountains of Cloudland and Rainfall, P. R. Jameson. Taylor Instrument Company, Rochester, N. Y. 10 cents.

4. Water Wonders Every Child Should Know, Jean M. Thompson. Doubleday, Page & Co.

PROJECT XIII

THE RELATION OF PLANTS TO MOISTURE

WE all know that there is a close relationship between plants and moisture. How they give off water; how much they give off; and how the water is obtained are problems to be solved.

Problem 1. Do plants give off moisture? — Under ordinary circumstances plants do not seem to give off water to the air, as the leaves remain fresh day after day. What happens, however, to leaves and flowers when they have been broken from the plant? What does this seem to indicate? How may these leaves and flowers be kept from wilting? The following experiment will enable us to find out if growing plants give off water.

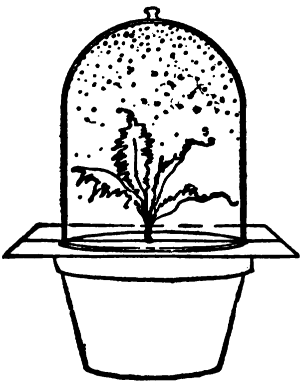


FIGURE 104. —TRANSPIRATION. What is the source of the water within the bell jar?

Experiment. — Completely cover the pot of an actively growing geranium or similar plant with rubber tissue or waxed paper, leaving only the stem and leaves of the plant exposed. Cover the plant with a dry bell jar. After a few hours observe and draw conclusions (Figure 104).

This process of giving off water by a plant is called *transpiration.*

Problem 2. The amount of water given off by plants.

Experiment. — Cover the pot of an actively growing geranium or similar plant with rubber tissue or waxed paper as in the preceding experiment. Weigh the plant and its pot. After the plant has stood in a warm room or outside the window if the day is warm, weigh again. Result. Roughly estimate the area of the leaves and calculate the loss of water per square inch or square foot.

Most persons are surprised when they realize the amount of water that is given off by plants. It has been calculated that an oak tree may give off from its leaves in the five months from June to October about 125 tons of water; and that a grass plot 50 by 150 feet may, under favorable conditions, give off by transpiration a ton of water in a day. A single corn plant was found to give off 31 pounds of water during its growth. It will thus be seen that the miles and miles of vegetation are continually giving back to the air the water which has been deposited on the earth in the form of rain.

Problem 3. How the root system of a plant is fitted to find water. — We all know that plants obtain water from the soil by means of their roots. Examine the roots of a plant and notice how they are fitted to reach many parts of the soil (Figures 105 and 106). There is a very close relationship between the development of the root system and the water supply.

Experiment. — Across the middle of a cigar box fasten an incomplete partition, not quite reaching the bottom of the box. In each compartment of the box, plant soaked pea seeds in moistened sawdust. Keep both sides watered until the seedlings have begun to form well-developed root systems. Then cease to water one side but continue to water the other side generously. At the end of two weeks carefully remove the sawdust and note the condition and arrangement of the roots. Conclusion?

In trees growing under normal conditions the roots extend out to a point directly under the outer ends of the branches. Why? Alfalfa plants growing in dry regions may have roots extending to a depth of 10 or 12 feet. Why? The mesquite plant living in the dry regions of the southwestern part of the United States and Mexico, although only a low shrub, may send its roots to a depth of 60 feet in

FIGURE 105. — UPTURNED SUGAR MAPLE.
Note the very large number of small roots.

search of water. Why does a lawn which has been sprinkled for a short time every day look worse after being neglected for a few dry weeks in August than the neighboring lawn which has not received the same care? Give one reason why weeds in a garden are harmful.

Problem 4. How roots are especially fitted to take in moisture. — You have probably noticed that even though

the greatest care be taken to prevent injury to the roots, a plant is apt to wither and be checked in its growth when transplanted (planted again after having been removed from soil in which it has been growing). This might lead us to suspect that there are special structures on the roots which are injured in the process of transplanting.

Growing roots in such a way that they can be examined without being disturbed may help us to find out if roots possess any special structures.

Experiment. — Place some radish seeds or other small seeds between a moist blotter and the bottom of a Petri dish or the inside of a test tube. Keep in a warm place and examine after three or four days. What do you find?

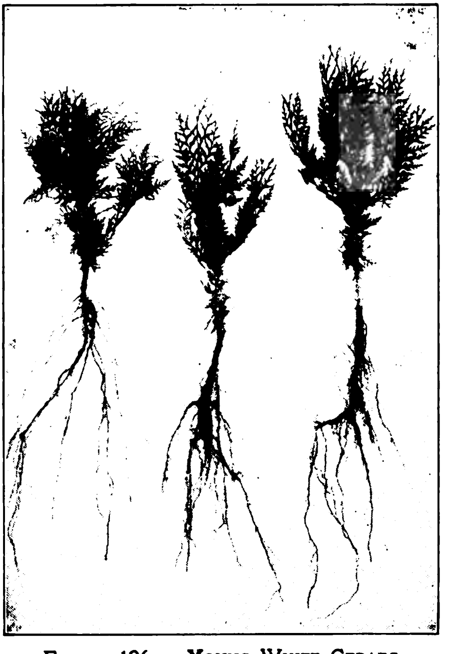


FIGURE 106. — YOUNG WHITE CEDARS.

The small hairlike structures which you see on the young root are called *root hairs* (Figure 107). Their structure, as you will see from the diagram (Figure 108), is very simple. Each hair consists of a delicate wall inclosing a thin layer of the living matter of the plant and some watery material called *cell-sap*. It will be noticed that the root hair is

only the extension of one of the little boxes containing living matter (cells) of which the young root is composed. Of what advantage are these root hairs?

FIGURE 107. — GERMINATING WHEAT SHOWING ROOT HAIRS.

Problem 5. How root hairs take in water. — The way in which root hairs take in water is illustrated by the following experiment.

Experiment. — Carefully chip off about one half of a square inch of the shell from the blunt end of a fresh egg, taking care not to injure the membrane lying under the shell. Support the egg at the top of a glass containing water so that the exposed membrane is immersed in the water. Puncture the shell and membrane at the other end of the egg and by means of a needle mix the white and yolk of the egg. Into this end of the egg fasten a glass tube with sealing wax, clamp the tube to an iron support and set aside for a few hours. What has happened? Explain how this illustrates the work of the root hair.

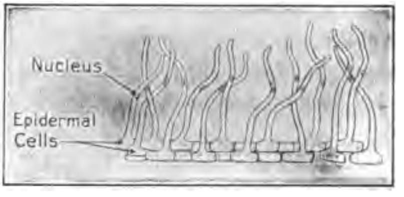


FIGURE 108. — ROOT HAIRS (enlarged).

Liquids separated by a plant or an animal membrane tend to mix with each other, but in this case the contents of the egg, like those of the root hair, are unable to pass through a membrane, so the flow of liquid is all in one direction. At

the same time that water passes into the root hair, raw food material needed by the plant also passes in. The part of the stem through which the liquids pass upward may be seen by cutting across a living twig, the base of which has been kept in red ink for several days.

FIGURE 109. — A LIVING TREE WITH A HOLLOW TRUNK.

What does this indicate as to the part of the stem through which liquids pass?

Problem 6. How water passes out of the leaves. — Does water pass out equally well from all parts of the leaf? This question may be answered by the following experiment:

Experiment. — Remove several leaves from a plant. Cover the upper surface of some of the leaves and the lower surfaces of others with a thin layer of vaseline. Examine after several hours. Which leaves have withered most? Conclusion?

Has the lower surface of the leaf any openings by which moisture escapes? To answer this question examine a bit of the membrane or epidermis stripped from the lower surface of a leaf (Figure 110).

The kidney-shaped cells (guard cells) on each side of the

openings (stomates) absorb, in moist weather, moisture from the air and swell up like the inner tube of an automobile tire when filled with air, making the opening or stomate large. In dry weather they lose their moisture, collapse, and make the stomate smaller. Of what advantage is this to the plant? Plants that live in dry regions possess various devices for the prevention of excessive transpiration, such as hairy, or thick-skinned leaves, or the reduction of leaf surface.

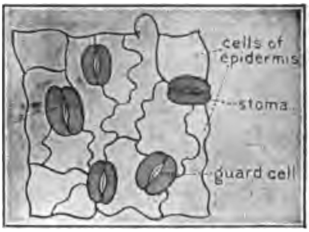


FIGURE 110. — LOWER EPIDERMIS OF A LEAF (highly magnified).

SUGGESTED INDIVIDUAL PROJECTS

1. Find out approximately how much water may be given to the air by a certain tree during one hour on a warm day in summer.
2. Find out the amount of water given to the air by a geranium plant in 24 hours.
3. Endeavor to find out the total extent of the root system of some plant.
4. Construct an apparatus to illustrate the action of the stomates.

REPORTS

1. Comparison of the kinds of plants in arid regions and those in well watered regions.
2. Importance of irrigation in the United States.
3. Dry farming in the Western States.
4. The salt supply of the United States.

REFERENCES FOR PROJECT XIII

1. Agriculture on Government Reclamation Projects, Scofield and Farrell. U. S. Department of Agriculture Year Book, 1916.
2. Irrigation and Drainage, F. H. Wing. Macmillan Company.

3. A Primer of Forestry, Gifford Pinchot. Government Printing Office, Washington, D. C.

4. First Book of Forestry, F. Roth. Ginn & Co.

5. Irrigation, Farmers' Bulletin 864. U. S. Department of Agriculture, Washington, D. C.

6. Dry Farming, Widtsoe. Macmillan Company.

PROJECT XIV

WATER POWER

IT is estimated that if the water power of the United States were fully used, it would be sufficient to run all the machines of our factories, to propel all railroad trains, street cars, and automobiles, and to furnish light and heat for the many

FIGURE 111.—TRAIN DRAWN BY AN ELECTRIC LOCOMOTIVE.
The power of this electric locomotive is derived from water power.

purposes for which they are used (Figure 111). At present only a small part of this power is being used, but the possibilities for the future are great (Figure 112). The questions that arise in our minds naturally are: What is the source of the energy or power of water power and where

and how can water power be best developed. Another problem somewhat associated in our minds with water power is the advantage gained by the use of hydraulic pressure.

Problem 1. What is the source of energy of water power? — What is the source of this energy which may be used in running water wheels or turbines, whose energy in turn may

FIGURE 112.—WATERFALL, MCKENZIE RIVER, OREGON.
Sufficient unused power to light a city.

be transformed into heat, light, electrical and mechanical energy (Figure 113)? We know that falling bodies exert energy, but no more than is put into them in raising them to the point from which they fall. The pile driver exerts energy in driving piles into the earth, but an engine must be used to pull the weight up to the place from which it is dropped.

In country houses, running water is frequently supplied

from an elevated tank. The energy possessed by the running water may be demonstrated by permitting it to run a water motor, which in turn may run a sewing machine, a churn, or a washing machine. Energy, however, usually supplied by a windmill or the burning of fuel in an engine must be used to pump the water into the tank. Thus the

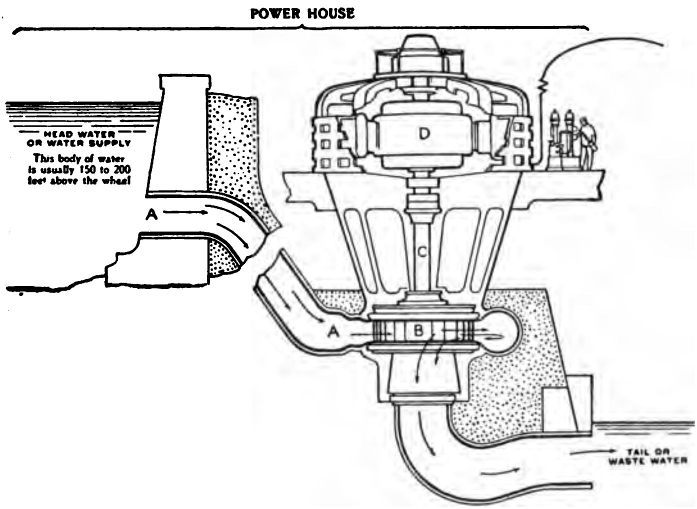


FIGURE 113. — DIAGRAM OF A POWER HOUSE.

Water passing through *A* turns the water wheel *B*. At *D* the energy of motion is changed by a dynamo into electrical energy.

energy set free by the windmill or by the burning of the fuel is transformed into the energy possessed by the water because of its position. We can understand now, that energy, or the power of doing work, exhibited by water in rivers and streams on their way to the ocean, must have been given to it in some way. The following suggestions may lead you to an understanding of the source of the energy of water power:

(*a*) What was the original location of the water concerned?

(*b*) What is happening to water on the surface of oceans and lakes?

(*c*) What is the relation of evaporation to heat?

(*d*) What is the source of the heat used up in changing the water into invisible water vapor, a gas?

(*e*) Just as steam, which is invisible water vapor, possesses energy, so this water vapor which results from the ordinary evaporation of water by the sun's rays has been given the energy which was used in changing the water into vapor.

(*f*) Because of the energy which it possesses, the water vapor is able to overcome the force of gravity (the force which draws things to the earth) and to move away from the surface. It is assisted in its movement by the currents of air and winds, which you will recall, are caused by the heat of the sun.

(*g*) When condensed into drops of water, the energy which the vapor possessed as a gas is changed largely into energy of position which is changed into the energy of water power, as the water travels in streams toward the ocean again.

In your own language, explain how water power depends upon the energy of the sun.

The energy of the water power developed at Niagara Falls, from the Mississippi River at Keokuk, Iowa, and in the streams which flow from the higher regions of the Appalachian Mountains, upper portions of the Great Lakes region, and the Rocky and Sierra Mountains, can be changed into electrical energy and be transmitted many miles to cities where it may be used to run mills and trains, and to furnish light and heat (Figure 114).

In order to make use of the water power of a river in which there are no falls but only a gradual slope of the river bed,

dams are built which raise the surface to a higher level. (Figure 115). By this means artificial falls are produced which may represent the natural fall of the river for several

FIGURE 114.—ELECTRIC HIGH TENSION TRANSMISSION LINE.
By these wires electric power developed by a waterfall in the mountains is carried to cities many miles away.

miles above the location of the mill or factory which is run by its power. Thus we may understand how water power can be developed from any stream in which there is an ap-

preciable current. Even in parts of the country which are relatively level, the mill dams from which power is developed to run flour or saw mills are common. With the

FIGURE 115. — WATER POWER STATION.

great demand for electricity there is need for the larger development of this source of power.

Problem 2. Source of the power of hydraulic pressure. — Hydraulic pressure which is used in barbers' chairs, in some kinds of elevators, and in various mechanical operations to produce great pressure, may be considered a form of water power. The following experiment may help us to understand how the great power of hydraulic pressure is obtained.

FIGURE 116.

Experiment. — Fill a bottle with water. Into the mouth of the bottle fit a perforated stopper which must be wired in or fastened by the device represented in the figure. Fit tightly into the opening in the

stopper a metal rod (Figure 116). Push down on the metal rod. What happens?

It is evident from this experiment that the force exerted on the inner surface of the bottle is many times the force exerted on the metal rod. This and other experiments show that the pressure on liquid, as water, inclosed in a vessel is transmitted undiminished in every direction and acts with equal force on all surfaces of equal area. This is known as *Pascal's principle* since it was first announced by Pascal, a Frenchman, in 1653. How the great force exerted by the hydraulic press is gained may be understood by studying the accompanying diagram which shows how a 1-pound weight may balance a pressure of 100 pounds. In commercial hydraulic presses, oil is generally used instead of water.

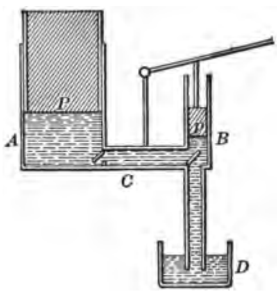


FIGURE 117. — HYDRAULIC PRESS.

A, large cylinder; *B*, small cylinder; *C*, connecting tube; *P*, large piston; *p*, small piston; *D*, reservoir for liquid.

By pushing down the small piston, a small amount of oil is forced into the space below the large piston. The force exerted upon the large piston is as many times greater than the force exerted upon the small one as the surface of the large piston is greater than the surface of the small one. A valve prevents the oil from passing out of the cylinder below the large piston.

Because of the great force exerted by the hydraulic press it is used in lifting heavy weights and in operations where great pressure is needed. Heavy machinery and crucibles filled with molten metal may be lifted with ease. Baling of cotton and paper, punching holes in steel plates,

making pressed steel and forcing lead through a die in the manufacture of lead pipe are some of the uses made of the enormous force exerted by the hydraulic press.

Suggested Individual Projects

1. Construct a water wheel which when operated by water from a faucet will run a simple machine.
2. Demonstration of the structure and action of a water motor.
3. Make a small hydraulic press.
4. Construct a map of the United States, and indicate in red the places where water power is utilized, and in blue other places where you think it might be used to advantage.

Reports

1. Utilization of the water power of Niagara Falls.
2. Water power development in different parts of the United States.

References for Project XIV

1. How It Is Done, A. Williams. Thos. Nelson & Sons. (Power from Niagara Falls.)
2. Harper's Machinery Book for Boys, Adams. Harper & Bros. (Water-Power.)
3. Practical Things with Simple Tools, Goldsmith. Sully & Kleinteich. (Making of Water Wheels.)
4. All about Engineering, Knox. Funk & Wagnalls. (Niagara etc.)

PROJECT XV

TO UNDERSTAND HOW COMMUNITIES OBTAIN A GOOD SUPPLY OF WATER

Water Supply of New York City. — The average daily consumption of water in New York City during the year 1917 was almost 600,000,000 gallons or 80,000,000 cubic feet. Naturally the question arises how such an enormous quantity of water can be supplied. Cities like Chicago, Cleveland, or Buffalo may get their supply from the great fresh-water lakes near which they are located. New York, however, is shut off from such a supply. When a small city, it depended largely upon wells; but as the population increased, such a supply became both inadequate and unsafe because of the danger of pollution. Beginning in 1842, water of the Croton watershed, an area of 375 square miles, about 22 miles north of the city, was collected in a number of reservoirs and lakes, and carried to the city by the Croton aqueduct.

With the enormous growth of population, even this great supply was found to be insufficient; and the city has obtained control of a large area of land in the Catskill Mountains, extending between 75 and 125 miles from New York. With the expenditure of about $200,000,000 there has been developed a water supply system which for many years to come will be able to furnish the city with the enormous quantity which it needs (Figure 118).

Problem 1. Why a wooded mountainous region is selected to furnish water. — You will notice that a wooded mountainous region has been selected as the water supply area. If the population of the city should increase to such an extent that the Croton and the Catskill regions would not furnish a sufficient supply of water, there is still the great Adirondack supply to be tapped. The advantages of selecting such a region may be understood from a consideration of the following questions:

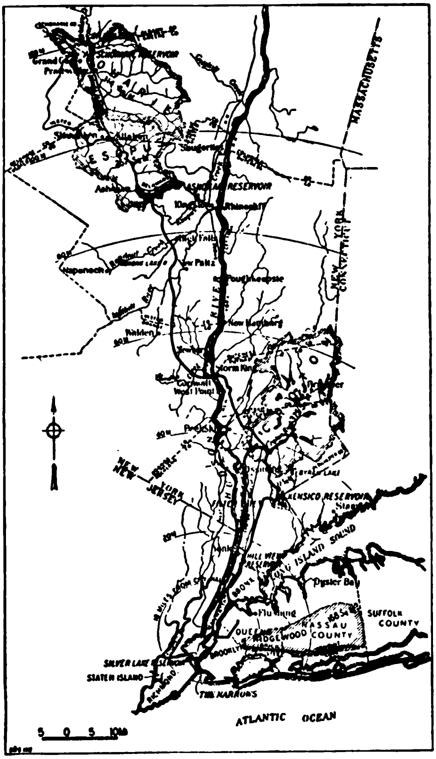


FIGURE 118. — SOURCE OF WATER SUPPLY OF NEW YORK CITY.

(*a*) From what direction do the moist winds of the eastern part of New York State come?

(*b*) What is the effect of the mountains upon these winds?

(*c*) Compare the agriculture of the mountains and the level country. How does this affect (*a*) the cost of acquiring the land, (*b*) the removal from cultivation of crop-producing land, and (*c*) danger from pollution?

FIGURE 119. — KENSICO DAM.

This is one of the greatest masonry structures in the world. It rises 307 feet above the rock foundation upon which it rests. Its thickness at its base is 233 feet.

(*d*) **Of what importance is the elevation of the source of supply to the water pressure in the pipes in the city? The**

FIGURE 120. — HEIGHT TO WHICH NEW YORK WATER WILL RISE WITHOUT BEING PUMPED.

water surface of the chief reservoir (Ashokan) of the Catskill system is 590 feet above sea level. Because water seeks its level, there is sufficient pressure to raise it to all floors of buildings of reasonable height, about 260 feet, without the use of pumps (Figure 120). It is estimated that this has saved an expense of $2,000,000 per year since the use of the Catskill supply began.

(*e*) Does the fact that the mountains are covered with forests make any difference? The floor of the forest, made

FIGURE 121. — FOREST FLOOR.

up largely of decayed leaves and interlacing roots, acts as a great sponge (Figure 121). What effect will this have at seasons of heavy rainfall? On the other hand, during dry weather the water which has been absorbed by the forest bed is gradually being given off, usually in the form of springs,

to the small streams which carry it into the collecting reservoirs (Figure 122).

Problem 2. How the water is protected. — The facts (1) that the people of New York City drink water drawn directly from the mains, and (2) that for many years there have been no epidemics caused by polluted water, lead us to wonder what precautions are taken to keep the supply

FIGURE 122. — A STREAM IN THE CATSKILL MOUNTAINS.
This is one of the feeders of the Ashokan reservoir of the New York City Water Supply.

pure, when we remember that the drinking of unboiled water from a stream is often very dangerous, and that the reservoirs are supplied largely by small streams.

We have already found that water in mountains is less apt to contain disease germs. Explain again the reason for this. A number of special precautions, however, have been taken to insure the purity of the water.

(*a*) In order to keep settlements at a reasonable distance from the shores of the Ashokan reservoir, the city has taken enough land to afford a marginal strip of at least 1000 feet wide around the shore. Explain the advantage of this.

(*b*) The reservoirs act as great settling tanks. Particles of dirt which have been carried into the reservoirs sink to the bottom, carrying with them the bacteria which may be

FIGURE 123. — AËRATORS.

Aëration of water before it passes into the great pipe that carries it to the City.

attached to them. Experiments have shown that practically no pathogenic bacteria will long survive under these conditions. Exposure of the water in the storage reservoirs to sunlight and air also assists in the destruction of any injurious germs that may be present.

(*c*) At the Ashokan and Kensico reservoirs aërators have been built (Figure 123). These consist of large numbers of nozzles through which jets of water are thrown into the air

as in a fountain. Not only do the oxygen of the air and the sunlight help to destroy bacteria, but unpleasant tastes and odors are removed and the water made much more palatable. The effect of aëration of water upon its palatability may be tested by first drinking some boiled water, and then drinking some which has been poured several times in a thin stream from one vessel to another.

(*d*) In addition to what may be called the natural agencies at work to make the water pure, chlorine gas (a very powerful sterilizing agent) is introduced into it just below the Kensico reservoir, if the bacteriological examination of the water

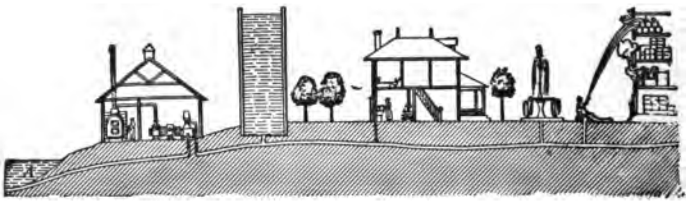


FIGURE 124. — DIAGRAM OF A CITY WATER SUPPLY SYSTEM.
Note pumping station, stand pipe, water supply for houses, fountain and fire prevention.

indicates the need for this treatment. The gas is wholly neutralized or dissipated before the water reaches the distribution pipes of the city.

Problem 3. How other cities obtain a supply of water.— Every large city has special problems to work out in connection with its water supply system. Many depend upon the collected rainfall from an area more or less controlled by the city, as New York does. Some depend partly upon artesian wells, which tap layers of porous rock that come to the surface sometimes hundreds of miles away and absorb much of the rainfall of that region. Others depend directly

upon river water which is purified by chlorination and the passage through great filters which remove much of the suspended matter. Still others may obtain water directly from large bodies of fresh water as do the cities on the Great Lakes.

Make a list of the uses of water in your community. What do you know concerning its water supply?

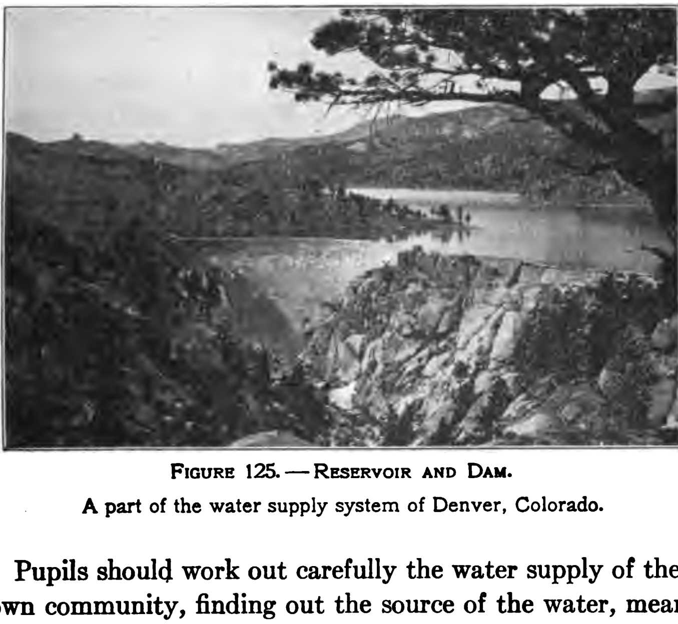


FIGURE 125. — RESERVOIR AND DAM.

A part of the water supply system of Denver, Colorado.

Pupils should work out carefully the water supply of their own community, finding out the source of the water, means taken to protect its purity, and how it is carried to the consumer.

Rural water supply. — Villages and individual homes in the country frequently depend upon relatively shallow wells, the water of which is of course supplied by that portion of the rainfall which has soaked into the earth. Great care

should be taken as to the location of such wells, and their protection from surface water.

In many cases, deeper wells which penetrate layers of clay or even rock are depended upon. The water of such wells frequently has minerals dissolved in it. Why? The water from wells in a limestone region will not form a lather with soap and is called "hard." This is due to the power of water to dissolve limestone. Illustration of this may be seen in any cemetery where there are old marble tombstones. What is the condition of the inscriptions on the stones? In some parts of the country, especially in Kentucky, Virginia, and Indiana, underground waters have dissolved away the rock to such an extent that large caves have been formed (Figure 126). Notable among these are Mammoth Cave of Kentucky and Luray Cave of Virginia. A tea-kettle in which "hard" water is used becomes incrusted on the inside with a grayish deposit which is really limestone.

FIGURE 126. — LIMESTONE CAVE.

Dissolved out by water. The projections from the roof were formed by deposits of particles of limestone from water trickling into the cave.

Problem 4. How the water system within the house should be cared for. — The water pipes in our homes are,

of course, direct continuations of the main pipes. What causes the water to flow out when we open a tap? Providing that there are no leaks, we need give the pipes very little attention. For convenience in repairing the pipes and faucets, there should be various places where the water may be shut off, and outlets by which the pipes may be emptied. In your own home locate these places.

Probably no part of the water system causes so much annoyance as the tank of the water closet. The working of one kind in general use is illustrated by the diagram (Figure 127). From the diagram explain how it works. Examine the way the tank in the water closet in your home is emptied and filled.

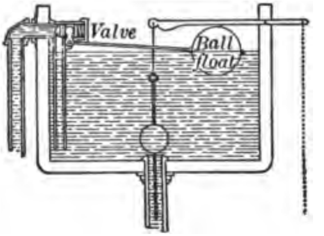


FIGURE 127.—WATER CLOSET TANK.

How does the water pass out of the tank? Notice the relation of the ball float to the opening and closing of the inlet pipe.

In winter there is danger of the water freezing in the pipes; and as water expands in freezing, the pipes often burst. This may usually be prevented by allowing the water to drip from the faucets on a cold night. Moving water does not freeze so rapidly as quiet water, as you know from observing the differing rapidity with which ponds and streams freeze. If a house is to be left vacant during the winter, the water should be drained from the pipes, and if there are portions from which the water cannot be removed in this way, a plumber should be engaged to "blow out" the pipes by forcing air through them.

Suggested Individual Projects

1. Construct a model of the water system of your community.
2. Determine the source of water of any springs in your vicinity.
3. Make a plan of water pipes in your house. Explain the advantage of this arrangement. In what way could the arrangement have been improved? Explain.
4. Demonstrate the structure of a faucet. Show how it may get out of order and what may be done to correct the trouble.
5. Study out the mechanism in the tank of the toilet in your home. Where is it apt to get out of order, and how may this condition be corrected?

Reports

1. Describe the methods used by a number of large cities to obtain a good water supply.
2. Tell how the American army was supplied with pure water in France.

References for Project XV

1. Home Water Works, C. J. Lynde. Sturgis.
2. Water Works in 38 Cities in Iowa, John H. Dunlap. University Extension Division, University of Iowa, Iowa City, Iowa, 5 cents.
3. Low Cost Farm Water Works, Conference for Education in the South. 508 McLachlen Building, Washington, D. C.
4. Drinking Water and Ice Supplies and Their Relations to Health and Disease, T. M. Prudden. Putnam.

PROJECT XVI

TO UNDERSTAND THE DISPOSAL OF SEWAGE OF HOMES AND COMMUNITIES

THE problem of getting rid of the waste of the home and of the community is almost, if not equally, as important as obtaining a good water supply. As in the case of the water supply its importance increases as cities increase in size.

Problem 1. Care of waste water pipes. — With regard to the waste water pipes which are connected with the sewers, we are chiefly concerned with the traps, — the usual form of which is represented in the diagram (Figure 128). Explain the need of a trap. What is apt to happen to a trap if considerable solid material is allowed to enter the waste pipe from the kitchen sink? This may be largely prevented if a sink strainer is used. Sometimes the grease from dishwater will collect in this waste pipe. This may be avoided by occasionally running through the pipe hot water containing lye. No trouble is likely to occur in the waste pipe of the water closet, providing that pieces of newspaper and matches are not thrown into it.

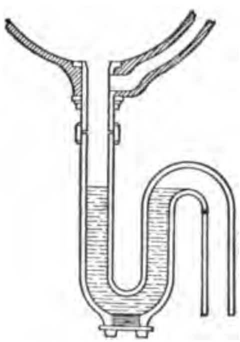


FIGURE 128. — TRAP OF WASTE WATER PIPE.

Problem 2. Sewage disposal in villages and isolated houses. — If we live in a city in which there is a well-

developed system of sewers there is really no concern for the individual home, other than to make sure that there is a proper connection with the sewer. In the home or school not connected with a sewer, the septic tank system is the most satisfactory. This consists essentially of two or sometimes three concrete underground tanks.

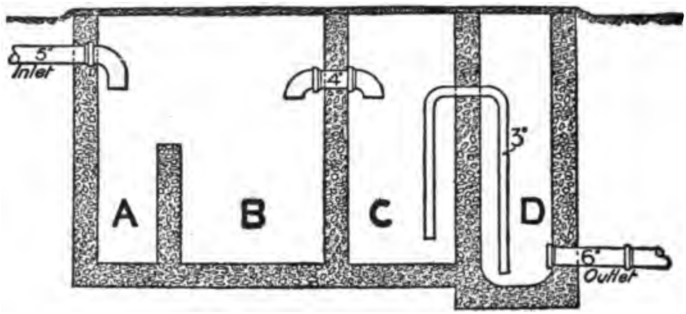


FIGURE 129. — SEPTIC TANK.

By the overflow pipe 4 the waste, liquified by action of bacteria, passes into *C*, from which it is siphoned into *D*, flowing out from there by the outlet pipe.

In the first tank, solids are acted upon by bacteria and liquified. By an overflow pipe this liquid passes into the second tank, from which it may be removed through the top; or, in the country, it may be conducted away by a series of drains and permitted to escape into the surrounding soil where it is soon completely decomposed by the soil bacteria. Any method of disposal of waste from the toilet in which the material is open to visits of flies, or in which it is permitted to become mixed with the soil before it has been acted upon for a long time by bacteria, is bad, as it may mean exposure to typhoid fever and hookworm disease.

Problem 3. Sewage disposal in cities. — The too common method has been the easiest; that of discharging sewage into

streams, lakes, or oceans. In the cases of cities like New York, located on the ocean, this method has not been so serious as in that of cities on lakes and rivers. Previous to 1900 the sewage of Chicago was emptied into Lake Michigan, from which body of water the city also obtained its drinking water. The average annual death rate from typhoid fever for the ten years preceding 1900 was 66.8 per 100,000. In that year the drainage canal was completed by which the Chicago River, which emptied into Lake Michigan, was connected with the Illinois River, which empties into the Mississippi River. So the lake water which now flows toward the Gulf of Mexico carries away with it the sewage of Chicago, leaving the lake uncontaminated.

In the ten years following the opening of the canal, the annual death rate from typhoid fever fell to 22.3 per 100,000. It was found that pathogenic bacteria in the Chicago sewage had disappeared long before the water had reached the Mississippi River. The chief influences that bring about such a condition are sedimentation, activity of other microorganisms, light, temperature, and lack of food supply.

Many cities use a method somewhat similar to the septic tank system on a large scale. The ideal plan would be such treatment of sewage that the products could be safely used as a fertilizer to enable the land to produce better crops. A moment's thought will cause you to realize what an enormous amount of material, which should be returned to the soil, passes to the ocean every day in the sewage from New York City alone.

Each pupil should find out the method of sewage disposal practiced by his community and determine the points in which the system is a good one and points in which it is deficient.

Suggested Individual Projects

1. Make a plan of the sewage system of your home. Point out the advantage of the arrangement. In what way do you think the arrangement might have been improved? Explain.
2. Clean out the various traps in the waste water system.

Reports

1. The transmission and the seriousness of the hookworm disease.
2. Sewage disposal of a large city.
3. Sewage disposal on a farm.

PROJECT XVII

WATER AS A MEANS OF TRANSPORTATION

In addition to the value of water in the air, as rainfall; in furnishing power, from waterfalls; for various industrial purposes; and for drinking and household uses, it also furnishes one of the chief means of transportation. The location of cities and the development of nations have been determined by opportunities for utilizing water transportation. The development of New York into one of the largest cities of the world has been greatly influenced by the fact that it possesses a harbor which is almost unrivaled. In the same way, Boston, Philadelphia, and Baltimore on the Atlantic Coast; St. Louis and New Orleans on the Mississippi; Chicago, Buffalo, Cleveland, Detroit, and Duluth on the Great Lakes; and San Francisco, Portland, and Seattle on the Pacific Coast, owe much to the advantages which they offer to water transportation. Africa has few harbors, Europe has many. Explain how this fact may have led to the more rapid development of civilization in Europe.

Since harbors to such a great extent determine the importance of a country, we naturally ask how a good harbor such as that of New York has been formed.

Problem 1. How the New York harbor originated. — Examine the outline map of the harbor (Figure 130). Examine also the coast of North America from Chesapeake Bay northward (Figure 131). Compare this coast line with

the western coast line of South America (Figure 132). There is evidence that the western coast line of South America is rising.

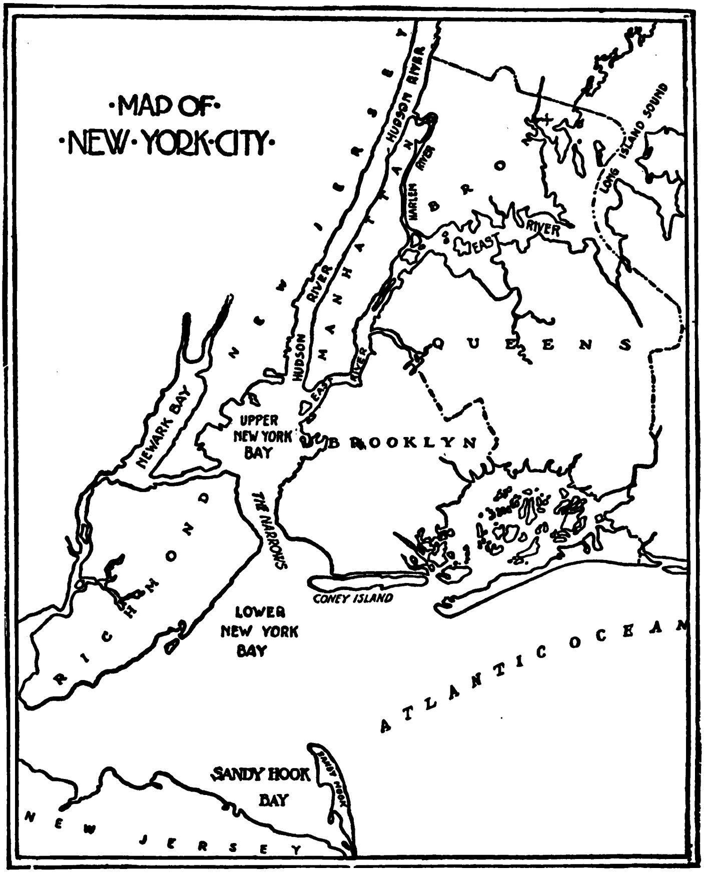


FIGURE 130.—MAP OF NEW YORK HARBOR.

Another fact to be noticed is that the Hudson River is very deep, permitting very large vessels to pass up its

waters a considerable distance. Those of you who are acquainted with the river know that the tide extends 166 miles up the river to Troy above Albany.

How can we explain the shape and depth of the harbor, the depth of the river, and the fact that the surface of the water of the river is at sea level for over one hundred and fifty miles above its mouth?

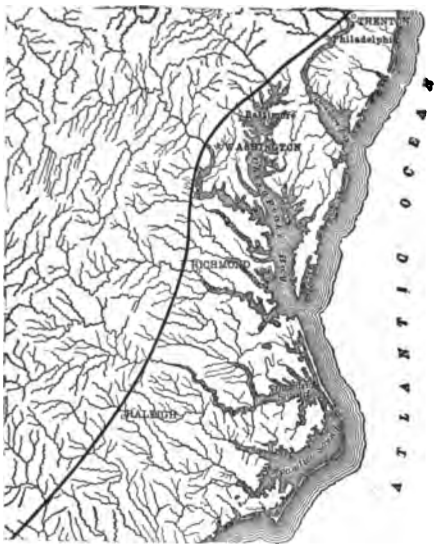


FIGURE 131.—COAST OF EASTERN UNITED STATES.
The heavy black line marks the distance the tide extends up the rivers.

Since the smooth coast line of western South America is known to be due to an elevation of the land, we might suspect that the very irregular coast line of eastern North America is due to a sinking of the land. If this is true will that account for the conditions of the New York harbor?

All evidence seems to point to the fact that New York harbor originated as did a great many good harbors by a sinking of the coast (Figure 133). This, of course, occurred many thousands of years ago in what we call prehistoric times.

From what we learn by studying the earth's crust we know that although we may think of the earth as the symbol

of solidity, portions of the earth's surface have at times been raised and at other times depressed. The stratified sandstone, limestone, and slaty rocks found over a great part of the country are evidences of the elevation of these portions of the continent, as these rocks are formed only at the bottom of the ocean (Figure 134).

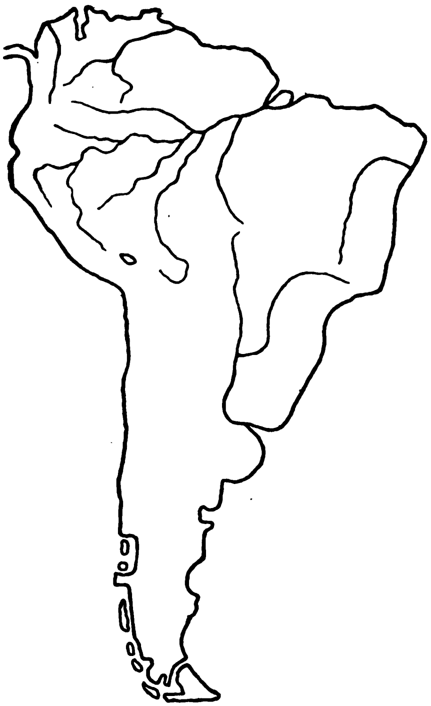


FIGURE 132.—OUTLINE OF SOUTH AMERICA.

Problem 2. Effect of the forests of the Adirondacks upon New York harbor and the navigability of the Hudson River. — In order that a harbor may be of the greatest value, a certain amount of dredging must be done to keep the channels free of sand and mud. The origin of this material will be understood by anyone who has noticed the appearance of the water in a small stream after a rainstorm. If this small stream empties into a large body of water, it will be noticed that the mud and sand, which is being carried, is dropped.

Streams everywhere are wearing away the land and carrying it to the ocean. This is the cause of much of the

irregularity of the land surface. Each little stream forms a ravine or valley of its own, carrying away the particles of earth and rock which have been loosened by changes of temperature, by the freezing of water in crevices, or by the action of the oxygen or carbonic acid of the air. The action of these agencies is known as *weathering*.

These particles, carried along by the swiftly moving water, help to wear away the bed of the stream; this is known as *erosion* (Figure 135). Thus we see that the land is gradually being carried to the ocean, where it is dropped as soon as the velocity of the water is checked by coming in contact with the greater body of water. Nearly all the streams that form the Hudson River begin in the Adirondack Mountains, about 3000 feet above sea level. What must be true of the velocity of the water of these streams? As the rainfall in the Adirondacks is not evenly distributed throughout the year, what would you expect to be the condition of the streams during the

FIGURE 133.—OUTLINE MAP OF ENGLAND.

Note the fine harbors at the mouth of the rivers. These were produced by a sinking of the coast many thousands of years ago.

season of great rainfall and at the time of the melting of the snow? What would you expect to be the result when this water meets the sluggish current of the tidal portion of the Hudson, and when the tidal current from the river meets the water of the harbor?

FIGURE 134.—STRATIFIED ROCKS.

You will be surprised to learn that the streams are not nearly so flooded, and that there is not so much sediment deposited as you would imagine. Our consideration of the effect of forests upon water-supply areas gives us the key to the explanation. The Adirondack Mountains are heavily forested. What effect does this have upon the volume of water in its streams? What also will be the effect upon the power of the streams to accomplish erosion and to carry mud, sand, and rocks? What do you think would be the

result of cutting the forests from this mountainous region as affecting the navigability of the Hudson River and New York harbor?

In parts of the country from which the forests have been removed, great floods occur in the rainy periods of the year, while at other times the navigable streams become too

FIGURE 135. — EROSION BY SMALL STREAM.
After heavy rains and after melting of snow this stream becomes a torrent. The forests on the mountains in the background have been burned away.

shallow to permit the passage of boats. Their navigability can be maintained throughout the year only by the expenditure of large amounts of money for the purpose of dredging the channels and of building dikes and dams.

These conditions are especially true of the Ohio River and its tributaries. A large part of the drainage area, which was at one time densely wooded, has developed into a rich agricultural region necessitating the removal of most of the forests. As a result, during the summer there is almost no

water except in the larger streams, while in the spring they overflow their banks, causing much damage to property and often loss of lives (Figure 136).

Problem 3. Importance of internal waterways. — For the transportation of articles of commerce in which speed is not a prime requisite, internal waterways might well be

FIGURE 136. — FLOOD IN WABASH RIVER, INDIANA.
This flood was due to the removal of forests from the region of the head waters of the river.

used far more than at present because of the smaller expense (Figure 137). This would also relieve the railroads so that their facilities might be used more completely in the transportation of passengers, mails, foodstuffs, and articles that demand quick delivery (Figure 138). Congestion of railroad traffic has been one of the causes of the high cost of living. In the great development of railroads during the past fifty years, the development of transportation by water has been neglected to a large extent. An illustration of the

great importance of river navigation is seen in the carrying of coal and iron from Pittsburgh down the Ohio and Mississippi rivers.

River traffic has been supplemented by the construction of canals. Many of these have fallen into disuse during the period of development of railroads, but recently steps have been taken to put some of them into a usable condition.

FIGURE 137.—USE OF RIVER FOR TRANSPORTATION OF LOGS.

The first half of the nineteenth century in the United States might almost have been called the era of canal building. Some of the canals were short ones around falls in otherwise navigable rivers. Many were of interest because they cut across watersheds and connected distinct drainage systems, frequently at the portages used by the Indians and early settlers. If railroads had not developed as they did, we should have had a very complete system of internal waterways.

The most important of these was the Erie Canal, completed in 1825 from Buffalo to Albany, a distance of 352 miles, connecting the Great Lakes with the Hudson River. Pennsylvania and Maryland attempted to connect their tide-water rivers with the Ohio River; Virginia endeavored to connect Chesapeake Bay with the Ohio River; in New Jersey the Morris Canal was built connecting New York City with the Delaware River; Ohio and Indiana built canals from the Great Lakes to tributaries of the Ohio

FIGURE 138.—USE OF INTERNAL WATERWAYS TO TRANSPORT FARM PRODUCTS.

River, and in Illinois a canal was constructed connecting Lake Michigan with the Mississippi system.

The "Soo" canal at Sault Ste. Marie, between Lake Superior and Lake Huron, and the Welland ship canal, between Lake Erie and Lake Ontario in Canadian territory, afford a continuous passage from all parts of the Great Lakes to the Atlantic Ocean by way of the St. Lawrence River. The route is of especial interest to us now because in the Great War many of the large lake vessels were brought to the Atlantic to be used to carry troops and supplies to

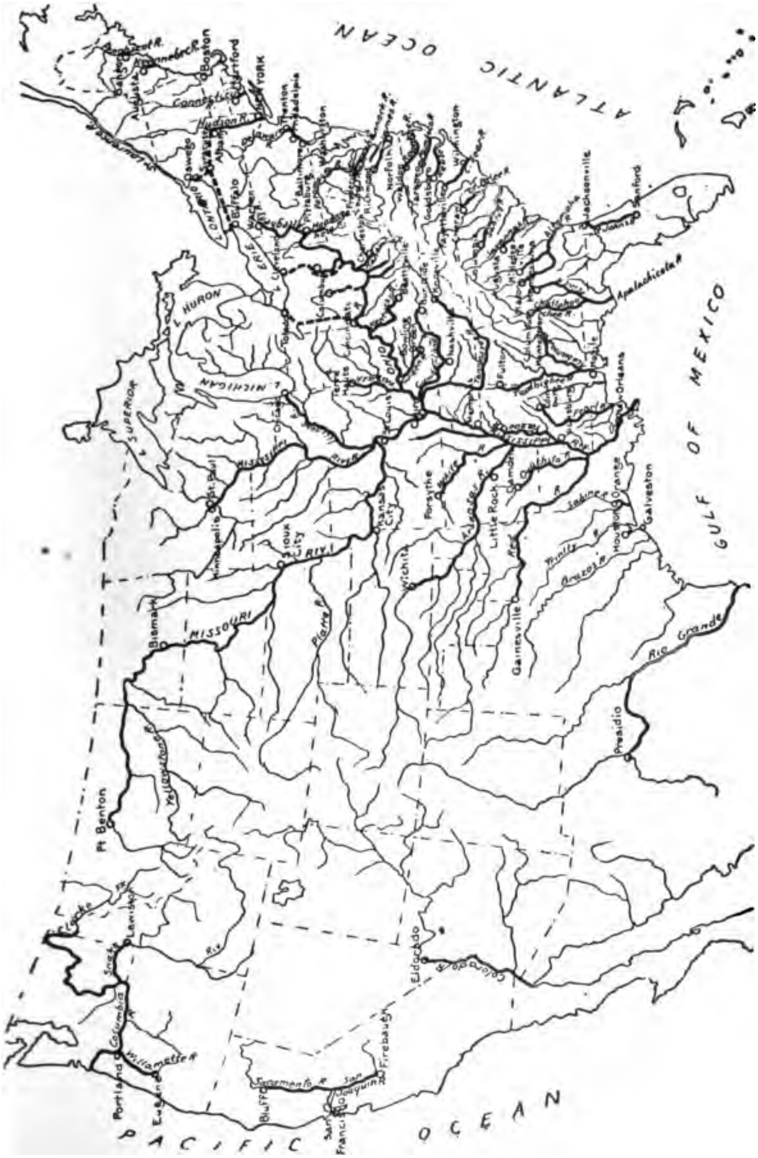


FIGURE 139. — POSSIBILITIES OF DEVELOPMENT OF INTERNAL WATERWAYS.
The deeply shaded portions of rivers either are navigable or could be made navigable with a relatively small amount of dredging.

Europe. This route has put great areas of our country into direct water connection with the markets of the world.

Problem 4. How ocean transportation depends upon science. — Ocean transportation follows regular routes which are determined to some extent by available harbors, prevailing winds, ocean currents, the probability of the presence of icebergs, and fogs. In a number of cases routes have been shortened by the construction of canals; the two most important ones are the Suez Canal through the Isthmus between Asia and Africa, connecting the Mediterranean Ocean and the Red Sea, and the Panama Canal through the isthmus between North and South America, connecting the Atlantic and Pacific oceans. Along our eastern coast, the Cape Cod Canal shortens very materially the coastwise route between New York and Boston. The Suez Canal, opened in 1869, has saved, in going from the North Atlantic to India and the Far East, the long trip around the southern end of Africa.

The building of the Panama Canal, opened in 1914, was the greatest engineering project of the world. Its influence upon the world's commerce is bound to be very great. It shortens the water route from New York to San Francisco by almost 8000 miles; from New York to Hawaii by about 6000 miles; from New York to Callao by about 6000 miles; from New York to Sydney, Australia, by about 4000 miles (Figure 140).

The building of this canal was not only an engineering triumph for the United States, but one equally great in the field of sanitation. American physicians, by their work in the canal zone, not only made possible the building of the canal but they demonstrated that tropical diseases are capable of human control.

FIGURE 140.—UNITED STATES WAR SHIP PASSING THROUGH PANAMA CANAL.

The sanitary work was under the control of Dr. William C. Gorgas, who built upon the work of the United States yellow fever commission in Cuba, consisting of Drs. Reed, Carroll, Lazear, and Agrimonte, who had proved at the cost

of the life of Dr. Lazear that the only way that yellow fever can be transmitted is by the bite of a certain kind of mosquito. Dr. Gorgas, who had already freed Havana and Cuba of the yellow fever plague, was appointed by President Roosevelt to continue the work which made possible the building of the canal. The French had been defeated by the mosquitoes years before in their attempt to build the canal without even having known that these insects were their enemies.

FIGURE 141.—MINOT'S LEDGE LIGHTHOUSE. This lighthouse is located on a reef near Boston Harbor.

That harbors are necessary for the best development of a country is realized in comparing the coast line of Africa with its few harbors to that of Europe with its many fine ones. Countries are ready to go to war to get an outlet to the sea. Because of the importance of ocean commerce,

nations have coöperated to encourage it in every way possible. The oceans and especially the waters near shores, where most danger lies, have been carefully charted; lines of magnetic force determined and charted; prevailing winds studied; great breakwaters constructed; harbor channels kept dredged; lighthouses, buoys, and foghorns placed as guides (Figure 141); life-saving stations located at intervals along the coasts; vessels and shipping offices furnished every day with weather forecasts and special warnings on the occasion of storms.

Since wireless telegraphy has come into use, a vessel may be at all times in touch with land stations and other ships, so that the danger of serious results from a breakdown, fire, or wreck at sea is very much minimized.

In addition to contributing largely to bringing about the conditions just mentioned, science is being called on for help in building larger, faster, and more seaworthy ships. In our own country the demand of the war for more ships has stimulated shipbuilding to such an extent that the United States is destined to become a leading ship-owning country. The ability of the captain to sail his vessel and bring it into port depends upon his scientific training and the scientific instruments which his ship carries. Without the mariner's compass, the sextant, the chronometer, together with his charts and nautical almanac, all the results of highly specialized science work, his ship would be an aimless wanderer.

Suggested Individual Projects

1. Make a collection of rocks from your vicinity accompanied by a story of the geological history of that part of the country.

2. Construct a model to illustrate erosion and deposit of earth and sand.

3. Construct a model canal lock by which boats in canals are passed from one level to another.

Reports

1. The general geological history of the North American continent.
2. A description of the work being done by the government to keep rivers and harbors navigable.
3. The story of the Erie Canal.
4. History of the building of the Panama Canal.
5. Means taken to prevent disease in the Panama Canal Zone.

References for Project XVII

1. Panama and the Canal, Hall and Chester. Newson and Co., New York.
2. Peeps at Many Lands (Panama, the Canal, etc.) Browne. Macmillan Company.
3. Historic Inventions, Holland. Geo. W. Jacobs Company, Philadelphia. (Fulton and the Steamboat.)
4. Book of the Ocean, Ingersoll. Century Co.

UNIT III

THE RELATION TO US OF SUN, MOON, AND STARS

PROJECT XVIII

TO UNDERSTAND THE CAUSE OF TIDES

ALTHOUGH so far away, the sun and moon exert a powerful influence upon everything that happens on the earth. This influence has been mentioned in considering the source of energy of food, coal, and wood, and the energy of water power.

Then too, the sun, moon, and stars, although so distant, have always been of the greatest interest to the inhabitants of the earth. The earliest speculations concerning things of Nature have been concerned with these heavenly bodies. We know now that much that was fanciful and erroneous crept into their ideas of these bodies; but we, just as our distant ancestors were, are interested in the wonders of the heavens. We, however, are not satisfied with fanciful imagination but want to know the truth

In our study we shall begin with one of the very evident ways in which the earth is affected by the nearest of these heavenly bodies, the moon. A study of the tides may give us some hints as to the relationship between the earth and other heavenly bodies and of the relation of these to one another.

If you live near the seashore or have ever visited it you know something about tides. Let us first get together our

FIGURE 142. — HIGH TIDE IN A HARBOR IN NOVA SCOTIA.

observations concerning tides. How many tides a day? Does high tide occur at the same time every day? If not, does it occur earlier or later each day? How much higher is the water at high tide than at low tide (Figures 142 and 143)? Are there any times when the tide is especially high? To find out the cause of tides it is evident that we must be able to solve the following problems:

What causes the rising of the water.

Why the water comes up twice a day.

Why high tide is a little later each day.

Why, at times, there are especially high tides.

FIGURE 143. — LOW TIDE IN THE SAME HARBOR.

Problem 1. What causes the water to rise. — From the fact that the highest tides occur at the time of the

full moon and the new moon, what will you suspect? But since the moon is about 240,000 miles from the earth, at first thought it seems hardly possible that it can exert a power sufficient to pull up such an enormous amount of water. This problem remained unsolved until Sir Isaac Newton, in the seventeenth century, showed that the force which causes an object to fall to the earth is the same force which causes this tidal wave approximately every twelve hours and twenty-five minutes.

In order to understand the cause of tides it is necessary for us to consider this force. The essentials of Newton's discovery are, that every particle of matter has an attraction for every other particle of matter; and that the strength of this attraction is directly proportional to the mass or amount of material and inversely proportional to the square of the distance between their centers. This means that if the moon were twice as large, it would pull upon the earth with twice the force it does now and that if it were twice as far from the earth as now it would pull upon the earth with a force only one fourth as great as at present.

In accordance with this *law of gravitation,* there is a pull between the center of the earth and every object we know. The measure of this pull constitutes the weight of a body. The reason that the earth does not seem to be pulled toward the ball that is dropping may be understood from the following experiment.

Experiment. — Connect two marbles, A and B, of equal size, by a rubber band. Draw the marbles apart and allow the elasticity of the band to pull them together. Compare the amount of movement of each marble. Now connect a very small marble with a very large one by a rubber band. As before, compare the amount of movement of each when they are pulled together by the elastic. If there is ten

times as much material in the large marble as in the small one, the large marble will move one tenth as far as the small one. Explain, then, why the ball falls to the earth, and why the earth does not seem to rise to the ball.

This force acts in solid bodies, through the center of mass of the body. It is because of this that a mason's plumb line points to the middle of the earth (Figure 144). In objects on the surface of the earth, this center of mass or *center of gravity*, as it is called, is the point of a body at which its weight may be counteracted by a single upward, vertical force.

FIGURE 144. PLUMB LINE.

The location of the center of gravity is easily found. Suppose the center of gravity of a piece of cardboard is to be found. Suspend the cardboard by a thread. Draw a line on it continuous with the line of the supporting thread. Now suspend the cardboard in the same way from another point of attachment. The point of intersection of the two lines will be the location of the center of gravity. Explain.

The fact that the center of gravity of a body tends to get as near the center of the earth as possible is illustrated by the tipping over of bodies. Why does a flat stone on the ground show no tendency to tip, while the same stone standing on its edge tips over very easily? A body is said to be in *stable equilibrium* when it cannot be tipped without raising its center of gravity; a body is in *unstable equilibrium* when it cannot be tipped without lowering its center of gravity (Figure 145).

Let us now go back to the tides and endeavor to understand how this force of gravitation causes them. The moon

attracts the solid earth as if the entire mass of the earth were concentrated at its center. The water of the ocean, however, is 4000 miles from the center of the earth. What, therefore, is the relative pull of the moon upon the solid earth, and upon the ocean on the side nearest the moon? (Figure 146). This is the cause of the tide on the side of the earth nearest the moon.

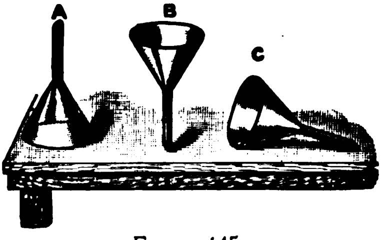


FIGURE 145.
A, stable equilibrium. *B*, unstable equilibrium. *C*, neutral equilibrium.

Problem 2. Why there are two high tides a day. — You already know from your study of geography that the earth rotates once in twenty-four hours. Therefore, how many

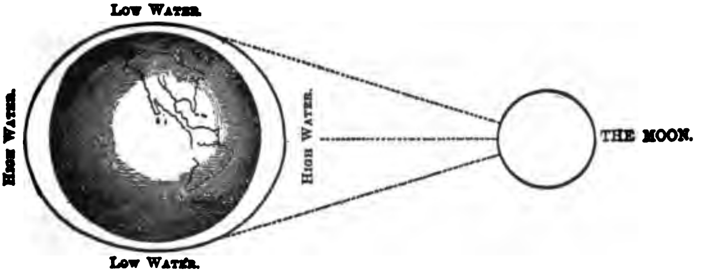


FIGURE 146. — RELATION OF MOON TO THE TIDES.

times a day is the moon directly opposite any part of the earth? It can be easily understood, then, how a wave of water will travel around the earth. In what direction will it travel? Explain. (Note: Does the moon rise in the east or the west?) According to this, how many high tides a day will there be? But, in reality, how many are there (Figure 146)?

From the fact that high tides are about twelve hours apart when there is high tide on any part of the earth, at what other part of the earth is the other high tide? Our problem then is, how is this second high tide, on the side of the earth away from the moon, caused.

Recall the way in which gravitation acts upon the solid earth and upon the water of the ocean. How much farther away from the moon is the water on the opposite side of the earth than the center of gravity of the solid earth? Upon which, therefore, will the pull be greater? It can be understood now how there is a tendency for the solid earth to be pulled away from the water and as a result the water will flow in, causing an elevation of the water, thus producing a tidal wave on the side of the earth away from the moon. In what direction will this tidal wave travel and at what rate compared with the tidal wave directly under the moon? There is also another force which helps produce this tidal wave on the side of the earth away from the moon, which can be understood a little later.

Problem 3. Why high tide is a little later every day. — From our discussion, what would you conclude should be the time between two high tides? If, then, high tide occurs at 12 o'clock on one day, at what time should there be high tide on the following day? Is this actually what occurs? Some of you have gone to the ocean bathing beaches. On your visits there did you find that high tide always occurred at the same time of day?

Observation will show you that high tide is about fifty minutes later every day. Our problem then is to understand the reason for this seeming discrepancy.

In our discussion of the cause of tides we considered that the earth rotated once in twenty-four hours. If the moon

kept in the same relative position with reference to the earth, how often would a certain point on the earth's surface be directly opposite the moon? Since, however, it takes twenty-four hours and fifty minutes for any spot which is directly opposite the moon to be again opposite the moon, what will be your conclusion as to the movement of the moon? Can you determine whether the moon moves around the earth in the same direction as the earth rotates or in the opposite direction?

Astronomers, scientists who study the movements of the heavenly bodies, have shown that the conclusion we have reached that the moon revolves around the earth in the same direction in which the earth rotates is true. They tell us that the moon revolves completely around the earth in twenty-eight days. We can now consider the problem which arose in discussing gravitation.

Problem 4. Why the moon does not fall to the earth. — You have probably wondered why, if the earth and moon are pulling each other, they do not come together just as we found that the rubber band pulled the two marbles together. In order to understand this, we must know that the moon revolves around the earth once in twenty-eight days. This is the explanation of the fact that the moon rises about one hour later every night. If the moon occupied continuously the same relative position to the earth, it would rise at the same time every night. What would be the time between high tides? What *is* the time between high or low tides?

The way in which the revolution of the moon around the earth prevents it from falling to the earth is illustrated by many very common happenings. What happens when you swing in a vertical circle a pail containing water? What

happens to the water on a grindstone, when it is turned rapidly? What happens to an automobile if it attempts to turn a corner too rapidly? What is the advantage of having a circular running track "banked"? Wet clothes are dried by putting them into a large, perforated, metal cylinder and rotating the cylinder rapidly. If you are familiar with milk separators, explain how the milk is separated from the cream (Figure 147).

All of these observations, showing that rotating bodies tend to fly away from the center around which the body is

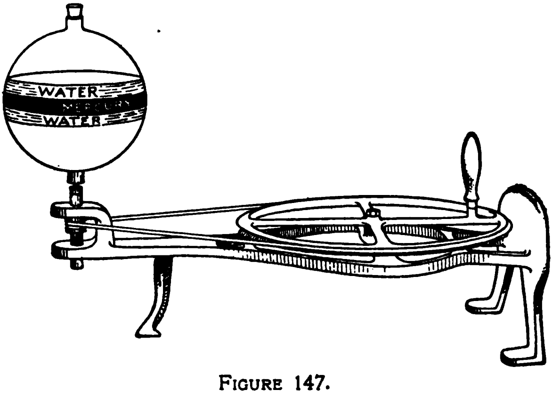


FIGURE 147.
Why do the mercury and water not remain at the bottom of the glass globe?

turning, are illustrations of the fact, that bodies in motion tend to remain in motion in a straight line. They are illustrations of a law stated by Sir Isaac Newton, known as Newton's first law of motion: "*Every body continues in its state of rest or of uniform motion in a straight line, except in so far as it is compelled by force to change that state.*" Give other illustrations of the law.

For every body turning around a center there must be two

forces; one drawing it toward the center, called the *centripetal force* (center-seeking force); and one drawing it away from the center, called the *centrifugal force.* The moon revolves around the earth once in every twenty-eight days. As the moon is 240,000 miles from the earth, you can easily calculate its velocity. Because of this motion what does the moon tend to do? What prevents it? In your own language explain why the moon is not drawn to the earth or does not fly off into space.

You will recall that in discussing the cause of the tide on the side of the earth away from the moon reference was made to another force in addition to the difference of the pull of gravitation upon the solid earth and the liquid ocean. This force we can now understand. The moon and earth are held together by the force of gravitation very much as a large man and a small boy might hold themselves together by locking their hands together.

If, while holding hands in this way, the man should swing the boy around, not only would the boy tend to swing in as large a circle as possible, but the coat tails of the man also would tend to fly out because of the centrifugal force. In the same way the water on the side of the earth away from the moon tends to heap up because of this centrifugal force.

There remains yet one problem concerning tides which we decided needed solution: Why, at times, there are especially high tides.

Problem 5. Why, at times, there are especially high tides. — Usually about twice a month the tides are especially high. During the winter of 1919–1920 such a tide accompanied by a wind from the ocean flooded Coney Island and Rockaway Beach near New York, wrecking

many buildings. At the same time a large part of the water front of New York City was covered with water.

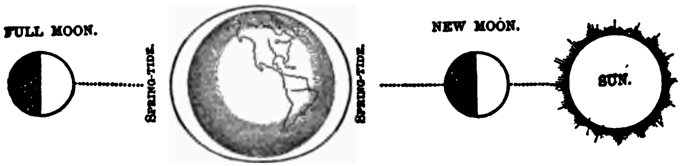


FIGURE 148.—THE TWO POSITIONS OF THE MOON WHEN HIGH TIDE IS HIGHER THAN USUAL.

This occurred at the time of the full moon. At every full moon and new moon the tide is especially high. On the other hand, when the moon is at first and third quarters, the high tides are especially low.

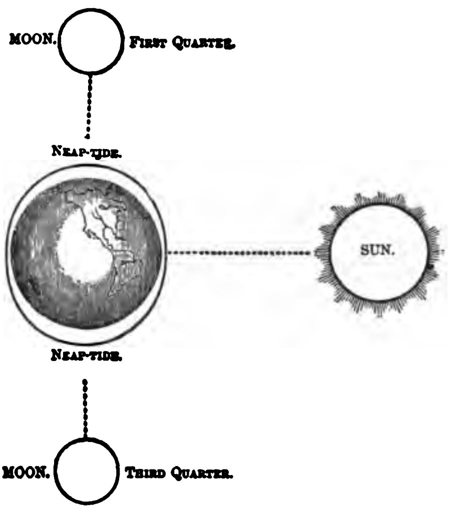


FIGURE 149.—THE TWO POSITIONS OF THE MOON WHEN HIGH TIDE IS NOT AS HIGH AS USUAL.

The accompanying diagrams (Figures 148 and 149) show the relative positions of the earth, moon, and sun at these times. From examination of these diagrams explain the cause of the especially high tides at certain times.

Evidently the theory that the tides are caused by the force of gravitation, studied by Sir Isaac Newton, can be accepted, as it offers a satisfactory explanation of the cause of tides and

is in harmony with all the facts that we have observed concerning them.

In mid-ocean the tide cannot be observed, but it is very noticeable when it strikes against the land. Sometimes because of the character of the coast line the tides rise to a great height, as in the Bay of Fundy, Nova Scotia, where they are more than sixty feet high. Some shallow harbors can be entered or left only at high tide.

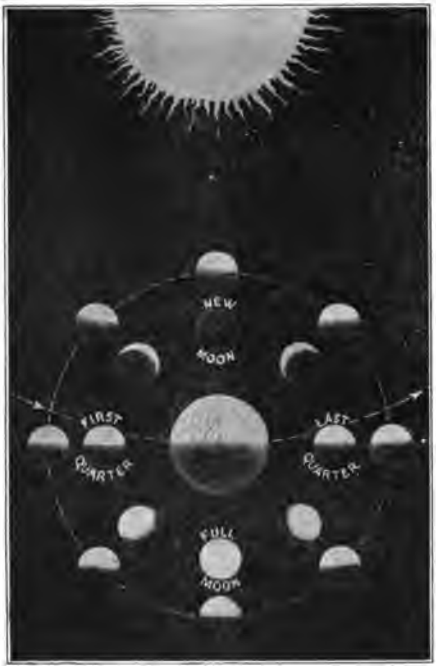


FIGURE 150. — PHASES OF THE MOON.

The outside circle of positions of the moon shows the part lighted by the sun. The inner positions indicate how the moon appears to us in its different positions.

Do tides possess energy? Can you suggest a way by which this energy might be utilized?

The information which we have learned concerning the movement of the moon around the earth may help us to solve another problem.

Problem 6. Why sometimes only a portion of the moon is visible to us. — At first sight this seems a difficult problem, but answering the following questions may help us.

1. Is the moon cold, or hot like the sun?

2. What is the source of the light which comes to us from the moon?

3. What motion has the moon in relation to the earth?

4. How long does it take the moon to go around the earth?

5. About how often do we have a full moon?

FIGURE 151.—A TOTAL ECLIPSE OF THE SUN.

An examination of the following diagram, in connection with the answers to the questions above, will make clear to you why, at times, the moon appears like a ball, while at other times it appears as a crescent. Even when the moon appears only as a crescent we can sometimes dimly see the remaining portion of its surface. This is because of reflection of light from the surface of the earth.

The following lines will enable you to know whether the crescent you see in the sky is an old or new moon:

"Oh, Lady Moon, your horns point toward the east. Shine; be increased!
Oh, Lady Moon, your horns point toward the west. Wane; be at rest!"

Occasionally an eclipse of the sun occurs. If we look at the sun at such a time through a piece of smoked glass, it will be noticed that a rounded black notch or patch appears on the edge of the sun. This black patch travels across the surface of the sun. If the eclipse is a total one, it obscures for a short time the entire face of the sun (Figure 151); if,

as is usual, the eclipse is only partial, only a segment of it is obscured.

Considering the relative location of the bodies of the solar system, what do you believe causes an eclipse of the sun? There may also be an eclipse of the moon. Suggest how this may occur. Draw diagrams showing the relation of the moon, earth, and sun in both kinds of eclipse. The accuracy with which the time of an eclipse may be foretold years in advance of the event is an indication of how thoroughly the laws of motions of the members of the solar system are understood.

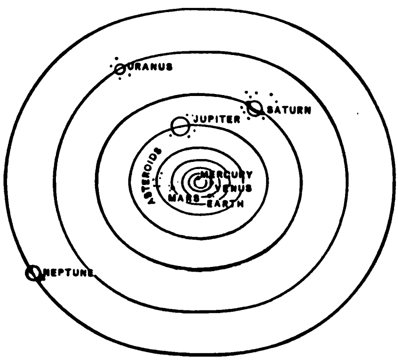


FIGURE 152.—DIAGRAM OF OUR SOLAR SYSTEM.

Solar system. — The same two forces which hold the moon in its path keep the earth and other planets in their orbits or paths around the sun. In the order of their distance from the sun the planets are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune (Figure 152) To us, Venus is the most conspicuous of these planets. Next to the sun and moon it is the brightest object in the sky. At times it is the evening star, and at other times the morning star.

Mars, which sometimes appears as a reddish star in the sky, has been a favorite object for study with the telescope because of its nearness and especially because in many respects it resembles the earth, leading observers to think that possibly life similar to that on the earth may exist there.

The thinness of the atmosphere and the small amount of water present on Mars render this belief rather improbable.

The sun with the planets revolving around it is called the *solar system*. The sun is a light-giving body; the planets and their moons only reflect the light of the sun.

Suggested Individual Projects

1. Make a model to scale showing the relative size of the moon and the earth, and the distance of the moon from the earth.
2. Make a diagram showing the location of the moon in the sky at a certain hour on six successive nights. Show also the appearance of the moon each night. Explain your observations.
3. Work out a plan of the solar system, representing to scale the relative distances and sizes of the sun and the planets.
4. Make a model of sun, earth, and moon to show the cause of eclipses, phases of the moon, and seasons.

Reports

1. Use of the energy of tides.
2. How the sun, moon, and planets have come into existence.
3. Discussion of the probability of life similar to that on this earth existing on other planets.

References for Project XVIII

1. The Moon, G. P. Serviss. D. Appleton & Co.
2. The Ways of the Planets, M. E. Marten. Harper & Bros.
3. Giant Sun and His Family, Proctor. Silver, Burdett & Co.

PROJECT XIX

HOW TO KNOW SOME OF THE FIXED STARS

THE thousands of stars which we see in the heavens are light-giving bodies, and correspond to our sun. Many or all of them may be the centers of solar systems. These stars have a fixed position with reference to one another and are accordingly called *fixed stars*. From the earliest times the stars have been grouped and named according to objects to which they seemed to bear a fanciful resemblance. The ability to recognize a few of the more easily located groups or " constellations " adds much to our enjoyment of a starry night

Problem 1. How to recognize the constellations around the north pole. — The easiest way to begin the study of the constellations is to locate the Great Dipper, which is known by almost everyone (Figure 153). While the Great Dipper is always in the northern part of the sky, it does not appear at all times in the same position, as the stars seem to revolve around a fixed point in the sky. The bright star located at this point is called the Pole or North Star. Explain why these terms are appropriate.

The Pole Star can be located by looking along a line which is a continuation of the line connecting the two stars forming the front of the bowl of the Great Dipper. These stars are called the Pointers. The Pole Star is along the line a distance of about five times the distance between the Pointers, or about twenty-five degrees, since the distance between the

Pointers is approximately five degrees. It will be well to keep these figures in mind, as they will serve as standards for measuring distances between stars.

The Pole Star is part of a constellation called the Little Dipper. It also has seven stars, the number that you have seen in the Great Dipper. The outline of the Little Dipper, however, is not so distinct as that of its big namesake. The Pole Star is at the end of the handle of the Little Dipper. The bowl is composed of a cluster of four stars, the two of the outer rim being the brightest, located about fifteen degrees from the Pole Star and facing the open bowl of the Great Dipper. If you have found the stars of the bowl, the other two stars of the handle may be easily located between the bowl and the Pole Star. It will be noticed that the end of the handle of the Little Dipper is bent in a different direction from that of the handle of the Great Dipper.

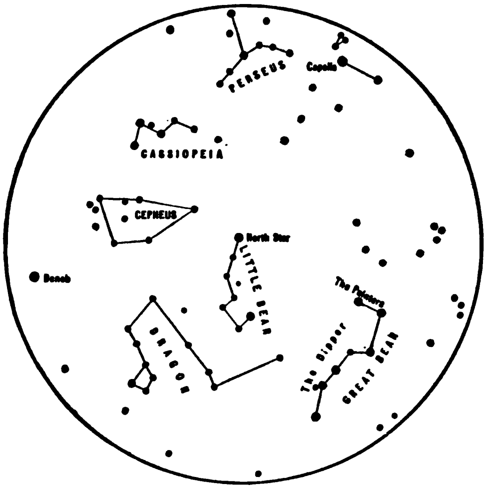


FIGURE 153.—CONSTELLATIONS AROUND THE NORTH STAR.

The ancients imagined the stars of the Great Dipper to represent the form of a great bear, and this constellation was accordingly called Ursa Major or the Great Bear.

Likewise the Little Dipper was called Ursa Minor or the Little Bear. The ability to see a small star in the handle of the Great Dipper is frequently used as a test for good sight. Look at the second star counting from the end of the handle. This is called Mizar. Directly above it at a distance of about one degree is the faint star Alcor. The Arabs call these two stars "the horse and the rider."

The constellation Cassiopeia's Chair is located about the same distance from the Pole Star as the Great Dipper, but on the opposite side. It is very easily recognized because its five bright stars form a W-shaped figure.

Auriga, or the Charioteer, contains one of the brightest stars, Capella, in the northern part of the heavens. Capella is about forty-five degrees from the Pole Star; that is, almost twice as far away as the Great Dipper or Cassiopeia's Chair, and on a line drawn at right angles to a line connecting the Pointers with the Pole Star. Another way to find Capella is to follow a line drawn from the star at the bottom of the Great Dipper that is nearest to the handle, and passing halfway between the Pointers. At a distance of about fifty degrees along this line, Capella will be seen as a very bright star. Capella with the four other brightest stars of the constellation form a pentagon or five-sided figure.

The brightest stars of the constellation Perseus lie in an arc extending from Capella to Cassiopeia's Chair. You will be able to see along this arc six or seven stars that belong to the constellation.

Other rather conspicuous constellations which may be seen within a radius of about forty or forty-five degrees of the Pole Star are the Dragon, and Cepheus.

Problem 2. How to recognize the constellations seen only in winter. — Stars farther away from the pole can be

seen only at certain times of the year. The best-known of the winter constellations, located on a line passing almost directly overhead from east to west, is Orion, the Hunter. It is easily recognized by the three stars forming the belt.

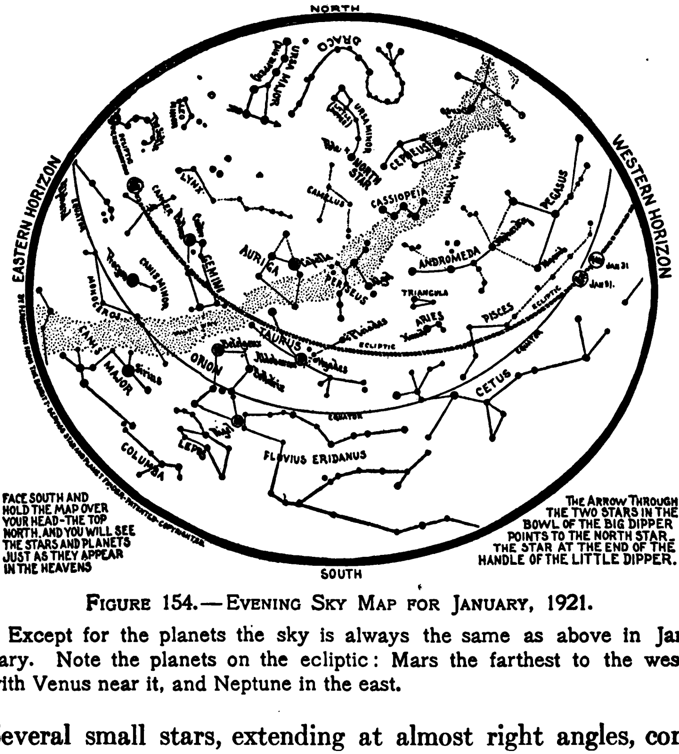


FIGURE 154.—EVENING SKY MAP FOR JANUARY, 1921.

Except for the planets the sky is always the same as above in January. Note the planets on the ecliptic: Mars the farthest to the west, with Venus near it, and Neptune in the east.

Several small stars, extending at almost right angles, constitute the sword hanging from his belt (Figure 154).

A very bright, reddish star, Betelgeuse,[1] marks the right

[1] The diameter of Betelgeuse was recently measured for the first time with an instrument devised by Professor Albert A. Michelson of the University of Chicago. The star was found to be about 27,000,000 times larger than our sun.

shoulder, while another bright star, Rigel, white instead of reddish, is located in the left foot of the great hunter. After you have located these stars, you will be able to make out the stars which represent the lion's skin which hangs from his left arm, and the stars of the right arm and of the club.

Facing Orion, and between him and the Pole Star, is the constellation Taurus, or the Bull. The face of the Bull is represented by several stars arranged in the form of a V. The bright red star, Aldebaran, at the top of the left branch of the V is the eye of the Bull.

The constellation called the Pleiades, or Seven Sisters, is in the shoulder of the Bull. The stars of this constellation, six of which can easily be seen, are very close together and arranged in the form of a very small dipper.

Farther south in the winter sky may be seen the constellations whose brightest stars, Sirius and Procyon, are called the hunting dogs of Orion. Sirius, the brightest of the fixed stars, seems to follow at the heels of Orion and may easily be located by following a line passing from the eye of the Bull, Aldebaran, through the belt of Orion and beyond about twenty degrees. Procyon, Sirius, and Betelgeuse make a triangle, each side of which is about twenty degrees.

If you have located the constellations which have been named in the preceding pages, you will be able with the help of the many excellent books about the stars, to locate other constellations, especially the most conspicuous ones of the spring and summer skies; the Lion and the Twins seen in the spring, and the Virgin, the Herdsman, the Northern Crown, and the Scorpion in the summer.

Suggested Individual Projects

1. Identify at least eight constellations.
2. Work out the method of reading star maps. Collect and mount star maps for every month.

Report

Origin of the names of some of the constellations.

References for Project XIX

1. A Beginner's Star Book, Kelvin McKready. G. P. Putnam's Sons.

2. The Barritt-Serviss Star and Planet Finder, Leon Barritt, 367 Fulton St., Brooklyn, N. Y.

4. Astronomy with the Naked Eye, G. P. Serviss. Appleton & Co.

5. Star Lore of All Ages, W. T. Olcutt. G. P. Putnam.

6. Earth and Sky Every Child Should Know, J. E. Rogers. Doubleday, Page & Co.

7. The Children's Book of Stars, G. A. Milton. Adam and Chas. Black, London.

8. The Friendly Stars, M. E. Marten. Harper & Bros.

9. The Stars and Their Stories, Griffith. Henry Holt & Co.

PROJECT XX

TIME AND SEASONS

SINCE light and heat come from the sun, the difference between winter and summer must be in some way associated with some difference in relation between the sun and the earth. Likewise our calculation of time must be based on the relation between the earth and the sun. Every morning we see the sun rise in the east and at the end of the day set again in the west.

Problem 1. Why we have winter and summer. — There are several facts with which we are familiar that will help us to understand the cause of the seasons. What is the comparative length of day and night during winter and summer? What is the relative height of the sun above the horizon at midday in winter and in summer? Evidently the sun shines more directly upon our part of the earth in summer than in winter.

We have already learned that the earth rotates (turns) upon its own axis, and revolves around the sun. If the axis of the earth is at right angles to an imaginary line running from the earth to the sun, what part of the earth would always receive the most direct rays of the sun? But since during the summer the portion of the earth north of the equator receives the most direct rays of the sun, and during the winter the same region receives fewer direct rays of the sun, what is your conclusion in regard to the direction of the earth's axis? (Figure 155.)

Since on our longest day in summer the direct rays of the sun strike a point 23½ degrees north of the equator and on the shortest day of our winter strike a point 23½ degrees south of the equator, we know that the axis of the

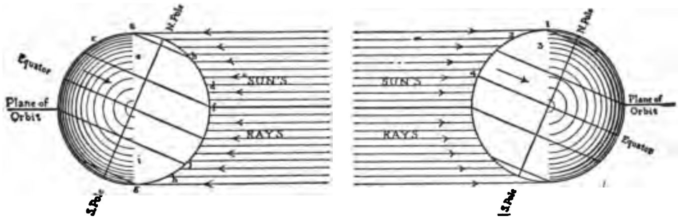


FIGURE 155.—HEAT FROM SUN, SUMMER AND WINTER.

earth is inclined 23½ degrees to the imaginary line running from the earth to the sun.

A careful study of Figure 156 will make clear how the revolution of the earth and the inclination of its axis cause the seasons.

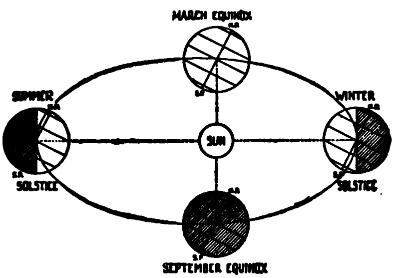


FIGURE 156.—PATH OF EARTH AROUND THE SUN.

1. At what times in the year are the days and nights equal in length? These times are called the *vernal* or *spring equinox,* and the *autumnal* or *fall equinox.*

2. On June 22, 1919, at New York City, the sun rose at 4:28 A.M. and set at 7:35 P.M. What was the length of the period of daylight? What was the length of the daylight period within the arctic circle (23½ degrees from the north pole) on this date?

3. In your own language discuss the changes in the length

of day and night starting with June 22, as the earth revolves around the sun.

Problem 2. Why July and August are the hottest months and January the coldest month. — According to the amount of heat received from the sun, what days of the year would you expect to be the hottest? Which is the chief source of heat of the air, the direct rays of the sun, or the heat given

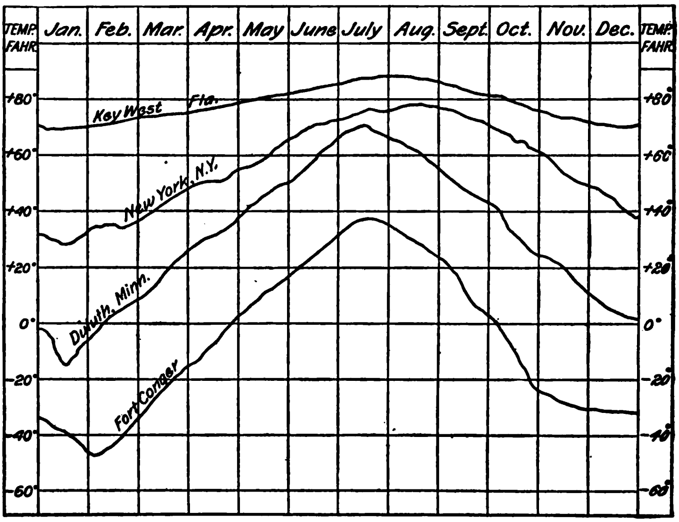


FIGURE 157. — ANNUAL TEMPERATURE CURVES.

Average annual temperature curves of two inland places and two places located near the ocean. Compare the maximum average summer temperatures.

out by the land and water of the earth's surface? (Of course, they too have received their heat from the sun.) What becomes of a large amount of the heat which comes from the sun during the latter half of June? What finally becomes of much of this heat?

It takes a considerable time to heat the land and water, and on the other hand they cool off gradually. Explain why January is colder than the latter half of December. You have already learned that bodies of land cool more rapidly than bodies of water. Explain, therefore, why coast cities have a later spring and winter than inland cities (Figure 157).

Why is the strip of land about ten miles wide along Lake Ontario the best peach-producing region of New York?

Problem 3. How time is calculated. — Some of us must have been surprised when we received news of the signing of the Peace Treaty before the time scheduled for the event to occur in Paris. Then we were told that the time at Paris was five hours faster than our own time; that when it is noon at Paris, our 7 o'clock morning whistles are blowing; and when we stop work for luncheon, the people of Paris and London are ready to quit work for the day, as it is 5 P.M. with them.

The general difference in time between different places may easily be understood when we consider that one complete rotation of the earth makes one day of 24 hours, and that noon by sun time at any place is the time when the sun is directly over a north and south line running through that place. In what direction does the earth rotate? In which city, New York or San Francisco, will 12 noon of a certain day first occur?

For convenience in comparing times and for the purpose of locating places on the earth's surface, imaginary lines (meridians) are supposed to be drawn around the earth from pole to pole (Figure 158). There are 360 of these equally distant from one another. Why 360? The distance between these lines is called a *degree of longitude*. Is a de-

gree of longitude always of the same length in miles? At the equator a degree of longitude measures about 69 miles. How much does a degree of longitude measure in miles at the poles? Usually the meridian passing through Greenwich, England, is called zero, and longitude is stated as east or west of Greenwich.

Since the earth rotates on its axis once in 24 hours, how many degrees of longitude will pass under the sun in an hour? Thus, for every 15° of longitude, the sun time of two places differs one hour. If our clocks were set strictly by sun time, what would be true of the clock time of every place east and west of a given place? In what way would this be inconvenient?

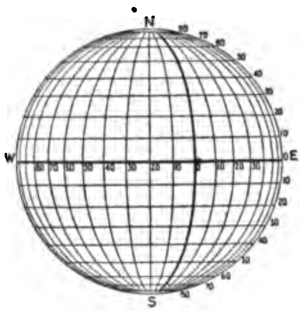


FIGURE 158.—LINES OF LATITUDE AND LONGITUDE.

To prevent the trouble and annoyance arising from such a condition, the United States Government in 1883, at the suggestion of the American Railway Association, adopted standard time. By this arrangement the time of the following meridians, 75th, 90th, 105th, and 120th, were taken as standards of time called Eastern, Central, Mountain, and Pacific Time. The area of the country to which the time was assigned extended approximately $7\frac{1}{2}$ degrees on each side of the standard meridian; the exact division being determined largely by the location of important cities (Figure 159). As a result, in going from New York to Chicago, we need to change our watches only once. Should the hands of the watch be advanced or turned back? How much?

Daylight saving. — On March 19, 1918, President Wilson approved a bill passed by Congress, by which the standard time throughout the United States was advanced one hour for the period beginning at 2 A.M. on the last Sunday in March and ending at 2 A.M. on the last Sunday in October. Suggest advantages of this bill to the various classes of people of your community. Does it seem to work a hardship to any? During the summer of 1919, because of objection to the daylight-saving plan by various interests of the country, Congress repealed the bill.

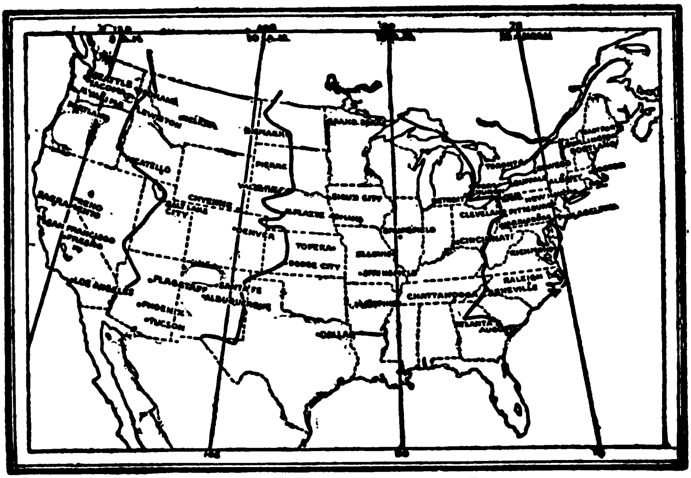


FIGURE 159. — STANDARD TIME BELTS.

The movement originated in England in 1907. It was not until 1916, however, that definite action was taken, when within three months daylight saving was adopted in England, France, Italy, Norway, Sweden, Denmark, Switzerland, Spain, Portugal, Holland, Germany, Austria, and Turkey. Practically no confusion resulted; everything went on as before, people doing exactly the same things at the

same time by the clock, but in reality the whole routine of life had been brought one hour nearer sunrise. The scheme had brought about in the simplest way a vital change affecting millions. A simple " twist of the wrist " had given these nations their " place in the sun." Friends of the movement in America claim that the annual conservation of coal in the United States would amount to no less a sum than $40,000,000 per season.

Problem 4. How places on the earth's surface are indicated. — A ship having become disabled at sea needs help. It has a wireless outfit for calling assistance, but how is it to indicate its position to the rescuing ship? Winds and currents may have carried it far out of its course. Evidently it is impossible to give its location by stating its position in miles from certain points. The officer in charge, by noting the difference between his sun time and the time registered by his *chronometer* (a very accurate clock) giving the time at Greenwich, is able to determine his position in degrees of longitude, east or west of Greenwich. Vessels within reach of wireless stations receive daily the correct Greenwich time. This is more satisfactory than dependence on chronometers. Why? The north and south position is determined by comparing the height above the horizon of a known fixed star as it crosses the meridian, with tables in his nautical almanac giving the height of this star above the horizon at different distances from the equator.

For example, where would the Pole Star appear to you if you were at the North Pole? Where would it appear to you if you were at the Equator? If you should travel from the Equator to the North Pole how would the position of the Pole Star seem to change?

The distance from the equator is measured by *degrees of latitude.* The equator is zero, and the poles 90°. Thus any place on the earth's surface may be accurately determined by giving its latitude and longitude.

The navigating officer of a ship with these means of determining his position, by consulting his charts and by the use of the compass is able to direct his course with surprising accuracy.

Suggested Individual Projects

1. Chart the position of the sun above the horizon at a certain hour every day for a month. Interpret the results.
2. At a certain hour one day each week determine the amount of earth surface covered by a column of sunlight whose cross section is one square foot.

Reports

1. Make a chart showing the relative length of day and night throughout the year. Accompany this by a diagram showing the cause of the differences in the length of day and night.
2. Make a chart showing the standard time belts.
3. Give method of determining latitude and longitude of a place.

UNIT IV

WORK AND ENERGY

PROJECT XXI

THE SUN AS A SOURCE OF ENERGY

THE question of energy and the work it makes possible has been an important part of almost every project and problem we have considered. It seems wise, however, to get together the knowledge we have already gained concerning work and energy and especially to take up the question of how man makes use of energy to contribute to his own comfort and to carry on the work of the world As the sun has been frequently mentioned as the great source of energy, our first project may well be the sun.

You will recall that we came to the conclusion that the energy of water power and of food and fuel could be traced back to the sun. Explain, therefore:

(*a*) The relation of the sun's energy to water power. Into what other forms may the mechanical energy of water power be transformed? (*b*) How the energy of the human body may be traced back to the sun. (*c*) How the energy obtained from the burning of coal and wood is really energy derived from the sun.

There is reason to believe that petroleum from which gasoline, kerosene, paraffin, and similar compounds are obtained, and natural gas, which in many parts of the coun-

try is used for fuel and lighting purposes, have been formed as a result of decomposition of animal and plant deposits. What, therefore, is the source of energy exerted by the engine of the automobile and airplane?

What do you consider to be the source of the energy of

FIGURE 160. — WINDMILL.
The machine at the left is one of the earliest reapers for the cutting of grain.

alcohol which may become the great fuel of the future if the supply of petroleum becomes exhausted. Alcohol is made by the action of yeast upon sugar.

The energy of winds also may be referred back to the sun's energy. Wind is not only used to propel ships but also to run windmills which are used especially for pumping water and grinding grain (Figure 160). The windmills of Holland are of considerable historic interest, but American

manufacturers are producing more efficient windmills than those of Europe. In some agricultural districts the windmill is very generally used for pumping water, although in recent years it is being replaced to a great extent by the gasoline engine. Suggest reasons for this.

Problem 1. How the sun's energy is used in making pictures. — You know that the light strikes the film or

FIGURE 161. — A NEGATIVE.

plate which is coated with gelatine containing a substance that is sensitive to light. When the film is put into a solution known as a *developer*, a black precipitate made up of minute particles of silver is produced wherever the light has struck the film. It is now washed in "hypo" (a solution of sodium thiosulphate) which dissolves out the sensitive compound which has not been touched by the rays of light.

The film, on which the dark parts of the object represented are light and the light parts dark, is now called a *negative* (Figure 161). This may be placed over paper

coated with a sensitive substance similar to that on the film, and exposed to light. The print which is produced has the light and dark places arranged just as they are in the object (Figure 162). Explain why this is true. Light other than direct sunlight may be used, but sunlight is much more active.

FIGURE 162.—PRINT MADE FROM THE NEGATIVE ON PAGE 221.

Blue prints. — Blue prints, which you have seen contractors and builders consulting, are copies of architects' drawings made in the following way. The drawing made in opaque ink upon transparent linen paper is placed over a sheet of paper which is coated with an almost colorless substance that becomes blue when exposed to the light. The print is then washed in water and the positions of the opaque ink lines appear white while all the remaining portion of the paper is blue.

You will recall from your study of oxidation that a change in which a new kind of a substance is produced is called a

chemical change. It is evident, therefore, that the changes produced by the sunlight in making pictures and blue prints are chemical changes.

Problem 2. Other chemical changes produced by the sun's energy.—The power of the sun's rays to produce what we call chemical changes, illustrated in the making of starch in plants and in the making of pictures, is also shown by some rather common phenomena. (*a*) *Fading of colors.*— (1) What is the appearance of portions of wall paper which have been covered by pictures as compared with the remaining part of the wall? (2) What is the appearance of your straw hat after it has been worn in the sunlight for several weeks? (3) Give other examples of changes of this kind which you have noticed.

(*b*) *Action upon living animals and plants.* — (1) What is the effect of the sun upon the skin? Will light of a gas or electric lamp, or heat of a stove or furnace, produce the same changes? (2) What is the effect of exposing to the sunlight parts of a plant that have been kept in darkness, as a potato or a stalk of bleached celery? (3) What is the effect of sunlight upon bacteria? This is the result of a chemical change in the living matter.

Problem 3. How direct use may be made of the sun's energy. — (*a*) *Cold frame and sun parlor.* — A large part of the sun's energy is turned into heat when it strikes the earth. Much of this energy radiates back into space, and while it is considered that no energy can be destroyed, yet so far as its utility to us on the earth is concerned, it is lost. The effect of clouds in preventing the direct escape of this energy into space has been touched upon elsewhere.

The cold frame and sun parlor are other examples of the capture of this energy (Figure 163). In both of these cases

rays of the sun, in the form of light, pass through the glass; but the heat into which it is changed does not pass through the glass easily, and as a result the space inclosed in the glass becomes considerably warmer than the outside air.

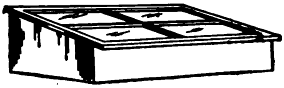


FIGURE 163.—COLD FRAME.

(*b*) *Solar engines.*—We sometimes wonder what the world will do for its supply of usable energy after the coal and oil deposits have been exhausted. Here we have suggested one possible solution. If the energy which is radiating into space could be caught and used, all demands of energy for light, heat, and power would be met. The amount of this energy is enormous; it has been calculated that the amount of energy of the sun's rays falling upon the deck of a ship when the sun is directly overhead, if turned into work without loss, would be sufficient to drive the vessel at a fair rate of speed.

FIGURE 164.—SOLAR ENGINE.

Efforts have been made to develop a solar engine by which this energy which now is lost to us might be applied to practical uses. In California, by means of great reflectors, the sun's rays were thrown upon the surface of a boiler composed of a coil of blackened copper tubing (Figure 164). Sufficient heat was developed to run an engine which

pumped water for irrigation purposes. The cost of the power, however, because of expense of construction and repairs, was much greater than if an ordinary engine had been used.

Other plants have been constructed in which the sun's rays were permitted to fall upon a series of shallow trays whose sides and bottoms were made of a substance which is a poor conductor of heat. The trays were covered with a double layer of glass which acted in the same way as the glass cover of a cold frame or sun parlor. Explain. A thin layer of water which flowed through the trays absorbed the heat.

The most successful plants for the direct use of solar energy have been constructed in northern Africa. Suggest a reason for this. Unfortunately, however, regions of this kind are not apt to become centers of industry. Why? This objection is now overcome to a great extent by the development of methods of transmission of electric power.

Problem 4. How the energy of the sun is maintained. — From what has been said in this chapter, what is your conclusion as to the source of all heat, light, and activity upon the earth? If the sun should become cold, do you think that the earth would continue to revolve around it, and rotate upon its own axis? Would the moon revolve around the earth? Would there be any seasons? Explain your answers.

This sun to which we owe so much has a diameter a hundred times greater than that of the earth, but it is located 92,000,000 miles from us. Evidently the earth receives an extremely small amount of the total energy sent out by the sun. This amount has been calculated to be about 1 part in 2,000,000,000. Although the amount of energy that is

being given off is almost beyond our imagination, yet there seems to be no lessening of it. Scientists believe that the undiminished supply is maintained by the heat and light which are produced as the particles that make up the sun, which is less solid than the earth, are drawn toward its center by the force of gravitation; the energy of gravitation being changed into radiant energy.

Therefore, it is believed that at present the radiant energy produced by contraction is equal to the amount of energy continually being given off by the sun. Of course, this cannot keep on forever, and in some future period, perhaps millions of years from now, the loss of energy from the sun will exceed the supply resulting from contraction, and the sun with its planets will gradually become dark and cold.

Suggested Individual Projects

1. Make a collection of articles showing the effect of the sun in causing colors to fade. Do any colors seem to be especially resistant to the action of the sun?
2. Demonstrate the process of making a photographic negative.
3. Demonstrate the process of making photographic prints.
4. Draw plans for something that you want to make, and make blue print copies of it.
5. Make a cold frame and use it in growing plants.
6. Make a sailboat and demonstrate how the wind makes it go in different directions.

Reports

1. Write a brief history of the development of photography.
2. Describe efforts that have been made to make direct use of the energy of the sun by means of solar engines.

References for Project XXI

1. How to Make Good Pictures, Eastman Kodak Co. Rochester, New York.

2. Something to Do, Boys, E. A. Foster. W. A. Wilde & Co.

3. Harper's Machinery Book for Boys, Adams. Harper & Bros. (Sun-power.)

4. All About Engineering, Knox. Funk & Wagnalls. (Power and Its Source.)

5. Boy's Book of Inventions, Doubleday, Page & Co. (Harnessing the Sun.)

PROJECT XXII

MACHINES

DURING the earliest periods of which we have any record, the earth was receiving just as much energy from the sun as at present. Little use, however, was made of this energy as compared with the present times. As man discovered the use of tools and then machines, civilization advanced. This is now an age of machinery. How man has multiplied his ablities by the use of machines is the project we have for solution.

Before we can understand how machines have enabled man to do much more than he could with his unaided hand, the meaning of several terms which have been used incidentally a number of times must be clearly understood.

Problem 1.. What is meant by work and force. — We have already defined energy as *the power to do work*, but just what do we mean by *doing work?* A man who digs a ditch or shovels coal is doing work. Steam which moves a piston, which in turn operates a pump, which lifts water to a tank on the roof, does work. This water in turn, we know, as it descends may operate a motor which will run a sewing machine or a churn, or may generate electricity which may run a motor, or be changed into heat to be used again in boiling water to produce steam. In raising the water, work is being done; also in the movement of the parts of the sewing machine or churn or dynamo, work is being done.

The essential of all these examples of work is that *there is*

the movement of a material thing through space against some resistance. What is the resistance that is overcome in lifting the water to the roof? In the sewing machine it is the *inertia* (the tending of a body to remain in the condition in which it is), the *friction* of the parts of the machine, and the friction of the needle as it passes through the cloth. In the same way, the electricity in moving the parts of the motor against resistance is doing work.

A boy who lifts a ten-pound weight from the floor to a table is doing work. If the boy holds the weight he is doing no work, although the muscles of his arms may become very tired. He is, however, exerting sufficient force to resist the force of gravity upon the ten-pound body. Since the body is neither raised nor lowered, the force he is exerting must be equal to the amount of the pull of gravity upon it.

FIGURE 165. — SPRING BALANCE.

Problem 2. How work and force are measured. — We measure forces in terms of pounds or grams of force. The weight of a body is the measure of the force of gravity upon it. Force, however, may be exerted in many directions. An easy method of measuring a force is by the use of a spring balance (Figure 165). Work considers the distance through which the force is acting. This may be well illustrated in the following way.

Experiment. — Attach a spring balance to a weight; pull on the balance until the weight moves, noting the number of pounds of force represented by the pointer. Suppose the pointer registers one pound of force; now pull the weight along one foot. The amount of work which is done is called one *foot-pound.* If the weight is moved two feet, two foot-pounds of work are performed. If the force necessary

to move a larger weight is two pounds, then the amount of work done in moving it one foot is two foot-pounds.

Time is not a factor in considering work done. Whether it takes one minute or a year to move an object a certain distance against a uniform resistance, the amount of work done is the same. You know that whether a man takes an hour or two days to shovel a ton of coal from one place to another, the work done is the same.

The rate of work is measured in the terms of *horse power*. This unit was chosen and named by James Watt who did so much for the development of the steam engine. A horse power was supposed to be the rate at which an average horse works. A machine of one horse power is able to do 33,000 foot-pounds of work per minute or 550 foot-pounds per second.

Problem 3. Reasons for using machines. — A device by which forces are advantageously applied to accomplish work desired is called a *machine*. Name the machines with which you are most familiar, and state the purpose of each. Explain, as far as possible, how the invention of these machines has resulted in the accomplishment of a greater amount of, or more satisfactory, work. The chief advantages gained in the use of machines may be made clear by a few simple examples.

FIGURE 166.

(*a*) What is the advantage of a claw hammer in pulling out a nail (Figure 166)? Can you exert sufficient force with the fingers to pull the nail? Give other examples showing that by use of a machine greater force may be exerted at a particular point.

(*b*) What are the advantages gained in the use of a sew-

ing machine? Why does a country doctor use an automobile instead of a horse and buggy as formerly? Give other examples showing how speed is gained by the use of machines.

(*c*) What is the advantage of using a single fixed pulley, as in raising a flag to the top of a flagpole? Give other examples in which an advantage is gained by changing the direction of the force.

Complex machines. — Most machines, such as a sewing machine, typewriter, clock, automobile, or threshing machine, are so complex that, at first sight, to gain an understanding of their mechanism seems almost an endless task. It will be found, however, that each of these machines is a combination of a large number of simple machines which can easily be understood. These simple machines are the lever, the wheel and axle, the pulley, the inclined plane, the wedge, and the screw.

Problem 4. How the lever is used in doing work. — 1. Let us suppose that a heavy rock must be lifted, and we find that we are unable to do it by hand. By the use of a strong beam or a crowbar (a strong steel bar) in the way indicated in the diagram, the lifting is accomplished with little difficulty (Figure 167).

FIGURE 167. — CROWBAR.

The bar constitutes a *lever;* the point on which it rests is the *fulcrum,* and the portions of the bar on either side of the fulcrum are the *arms.* The amount of force that must be applied may be determined by the following experiment.

Experiment. — Use a yard or meter stick as the lever; use a 10-pound weight, placing the lever on the fulcrum in such a way that one arm is ten times as long as the other. Place small weights on the

end of the long arm until the lever balances on the fulcrum and the weight is lifted from the table. What weights have you placed on the long arm? Vary the experiment by putting the fulcrum at different places, thus changing the relative length of the arms.

It will be noted that the force needed to lift the weight is inversely proportional to the length of the arms. Therefore

$$\text{effort} \times \text{its arm} = \text{weight or resistance} \times \text{its arm}.$$

The slight variations from this are due to the weight of the lever, and the small amount of friction between the lever and fulcrum. Measure the distance through which each arm moves. What are your conclusions? Compare the amount of work done at the end of each arm.

FIGURE 168. — TONGS.

Why such a long handle?

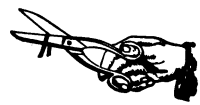


FIGURE 169. — SCISSORS.

Why is the cord not cut by the end of the scissors?

This experiment is duplicated in the action of the seesaw which most of you have tried. What is the position of a heavy boy and that of a light boy? Compare the distances through which each moves. Give all the uses you can of levers of this kind (Figures 168 and 169). These are called *levers of the first class.*

2. Considering the wheelbarrow as a lever, where is the fulcrum, the resistance or weight, and the effort or power? Why is it easier to lift a bag of flour in a wheelbarrow than directly by hand? Would making the handles longer cause it to be harder or easier to lift the load? Why are the handles not made longer? Give other examples of levers with the same relative arrangement of fulcrum, resistance or weight, and the effort or power (Figure 170). In these levers

compare the length of the power arm and the entire lever. These are called *levers of the second class.*

3. Considering a pitchfork or a fishing pole as a lever, where is the fulcrum, the resistance or weight, and effort or power? What is the advantage in using such a lever? In using a pole 10 feet long, about how much force must be used to land a fish weighing 5 pounds? What are the advantages and disadvantages of using a very long handled pitchfork? Give other examples of levers of this kind. They are called *levers of the third class.*

FIGURE 170. — NUTCRACKER.

4. Explain how the bones of the human body act as levers during walking, running, lifting, and throwing (Figure 171). To which class of levers do they belong?

Problem 5. How wheels are used in doing work. — Wheels are so commonly used in machines that when most of us think of machines and machinery, we also think of wheels. Like the lever, they may be used to gain force at the expense of distance or speed, or may be used to obtain speed or distance at the expense of force, or may be used to change the direction of the action of a force as in the beveled cogwheels used in transmitting the power of the crank shaft to the inner axle which turns the wheels of an automobile.

FIGURE 171. — ARM AS A LEVER. Estimate force necessary to lift a 10-pound weight.

1. *The windlass.* — One of the most easily understood examples of the action of the wheel and axle is the case of the windlass which is used to draw water from a well, raise

the anchor of a ship, or move buildings (Figure 172). Most of us have seen the delivery man on a coal wagon raising the bed of the wagon containing several tons of coal by turning a crank at the side of it. It does not seem difficult, although he is raising a weight many times greater than he would be able to lift unaided. The reason for the use of the crank, which is really only a spoke of a large wheel, may be understood by considering it as a lever.

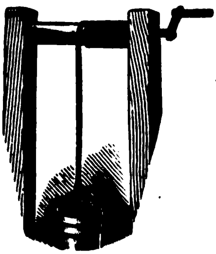


FIGURE 172. — WELL WINDLASS.

Comparing this with a lever, what may be considered to be the fulcrum, what the power arm, and what the weight or resistance arm? Explain the advantage in the use of the windlass, and its modifications in pulling or lifting heavy weights. Explain the ease with which the grains of coffee are crushed by the hand coffee grinder, and with which meat is chopped by the kitchen meat chopper.

2. *Cogwheels and wheels moved by belts.* — In machines much use is made of cogwheels. With these, as with other simple machines, power may be gained at the expense of speed, or speed may be gained at the expense of power. The high and low speeds of the automobile illustrate this fact very well. Along the level road the car runs in high gear; but as soon as it begins to climb a steep hill, the driver, by means of a lever at his side, shifts the gears so that a different cogwheel (a larger one) engages the crank shaft. The machine now has greater power, but less speed. Most automobiles have three speeds; first, second, and third, and the force exerted by the machine is in inverse ratio to the speed.

With an apparatus such as shown in the diagram (Figure 173), state how much force must be applied on the crank to exert a pull of 2000 pounds.

In bicycles and in some motor trucks, a chain is used to transfer the power exerted by the pedals upon the sprocket wheel to the axle of the rear drive wheel. In this case as in cases of cogwheels that are in contact or mesh directly, the greater the size of the sprocket wheel, the greater the speed the machine possesses, with, however, correspondingly less power to climb hills.

FIGURE 173.—PART OF A DERRICK. Combination of wheel and axle and cogs

Belts are very commonly used in factories to convey power to machines. By a graduated series of wheels, the speed and the force exerted by the machine may be regulated. A very simple example is seen in the foot power sewing machine. The heavy rim of the small wheel, because of its inertia (the tendency of a body to remain in the condition of rest or motion in which it is), makes the running of the machine much more even, just as does the flywheel on an automobile.

Why is the belt wheel on an engine that runs a threshing machine large, while the belt wheel of the threshing machine itself is small? Belts are able to move the wheels because of friction between the belt and the wheel.

Problem 6. Why pulleys are used. — We can raise a window fitted with weights any distance and it stays there. The pulley reduces the friction. If the cord supporting

FIGURE 174. — PLACING HEAVY PIPE IN POSITION.

Use of block and tackle in putting in place heavy steel pipe, in construction of an aqueduct. The aqueduct shown here is now used to carry water from the Catskill Mountains to supply New York City, miles away.

the weight ran through the opening in the window casing, without the pulley, would the window move so easily, and what would be the condition of the rope and the edge of the

opening in a short time? Frequently, clothes lines extend from windows of an apartment building to a pole or to the opposite side of a courtyard. Explain how the clothes may be hung on the line for its whole length though it is far above the ground. What is the advantage of using a pulley in this case? Explain the importance of a pulley in raising a flag to the top of a pole. If a pulley were not used, how could the flag be placed in position? In these cases where a single fixed pulley is used, is there any gain in force applied or distance covered?

Use of pulleys in hoisting heavy objects. — We have all seen pianos being raised to the upper windows of buildings. It seems rather easy, one man being able to raise one, although we know that lifting a piano is difficult even for several men, without some kind of apparatus. In the same way, heavy blocks of stone or steel girders are lifted into place during the construction of a building (Figure 174). Observation will show that pulleys are used, usually in the form of what is known as a *block and tackle.* The value of the pulley can be understood by an examination of the diagrams and by a few experiments.

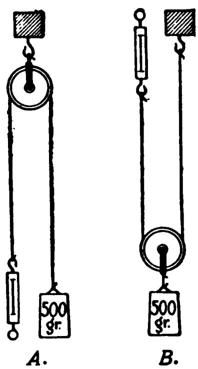


FIGURE 175.

Experiments. — (*a*) In both *A* and *B* (Figure 175) if the weight is 10 pounds, what does the spring balance register? To raise the weight 6 inches, how far must the cord to which the spring balance is attached be pulled? In this respect compare work done by pulley with work done by lever, and by wheel and axle. What is the purpose of using the fixed pulley?

(*b*) In the block and tackle represented in Figure 176, how many sets of pulleys are there? How much force must be exerted in using this machine to lift a weight of 300 pounds if the weight of the pulley

itself is ignored? How far will the rope have to be pulled to lift the weight 10 feet? In lifting heavy weights, the power rope is usually connected with a wheel and axle. Explain the reason for this. Where have you seen sets of pulleys such as this used?

FIGURE 176. — BLOCK AND TACKLE.

Problem 7. How inclined planes are used in doing work. — Which seems to demand more effort; walking to the top of a hill up a gradual slope, or up a very steep one? In parks which have hills, how are the paths laid out? In going up mountains, railroads take a very winding or zigzag course instead of going directly up. Wagon and automobile roads are built in the same way where a considerable elevation is to be reached (Figure 177). An automobile which fails to go to the top of a hill at high gear, if the road is one fourth of a mile long, will go up easily at this gear if the road is several times longer. In pushing a heavily loaded wheelbarrow into a door which is a foot above the ground, is it better to use a board 2 feet long or one 3 feet long, reaching from the doorsill to the ground?

What conclusion do you draw from these points to which your attention has been drawn, and from other similar cases which you have observed? Evidently in these cases as in the use of the lever, the windlass, and the pulley, in doing a specified amount of work, the greater the distance through which the force or effort works, the less is the required effort.

The following experiment will show the relation of effort

FIGURE 177. — ROAD NEAR COLORADO SPRINGS, COLORADO.
Note the grade necessary if the road ran directly to the point where it disappears.

to length of the plane in raising a weight by the use of the inclined plane.

Experiment. — Take a smooth board 4 feet long; raise one end of the board 1 foot from the ground (Figure 178). Into a toy wagon put weights until the wagon and its contents weigh 8 pounds; attach a spring balance to the front of the wagon and by means of it pull the wagon up the incline, taking care to keep the spring balance parallel with the board. What does the spring balance register? (The spring balance will register somewhat too high because of the friction between the wheels and the board.)

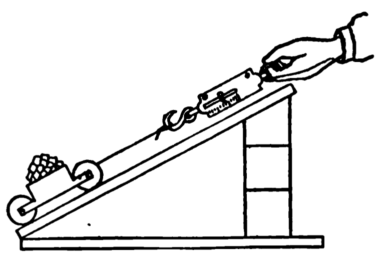


FIGURE 178.

Change the raised end of the board to 2 feet above the ground, and then to 4 feet, making note of the force necessary to pull the weight

up the different inclines. Draw your conclusion as to the advantage of the use of the inclined plane.

Wedges (Figure 179), chisels, knives, and common pins are all really inclined planes. One of the most interesting of modified inclined planes is the screw (Figure 180), which has many uses with which you are familiar. All screws are inclined planes, as may be shown by the following experiment.

FIGURE 179. — WEDGE.
Is a thick or a thin wedge easier to drive in?

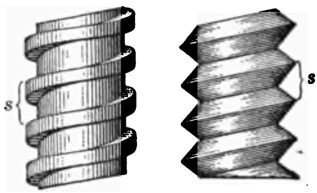


FIGURE 180. — SCREW.
How much is head of screw lowered in complete turn? *s*, pitch of screw.

Experiment. — Cut a piece of paper into a right-angle triangle, with the shorter side of the triangle 2 inches and the longer one 8 inches. Wind the paper around a pencil, beginning with the short side parallel with the pencil (Figure 181). What is the appearance of the paper after it is wound around the pencil?

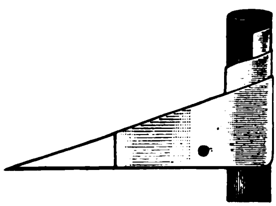


FIGURE 181. — DEMONSTRATION THAT SCREW IS AN INCLINED PLANE.

You will now understand how a jackscrew (Figure 182) is of assistance in raising a building or a heavy weight, or how greater pressure may be brought to bear by the use of a screw clamp, by the nut on a bolt, or by presses of various kinds in which screws are used. The efficiency of the

FIGURE 182. — JACKSCREW.

screw as a machine is usually increased by the use of a lever.

Examine various complex machines and determine in what way these simple machines are combined, and the special advantages of the use of each.

Problem 8. Why machines are not 100 per cent efficient.— Ideally, what should be the amount of work obtained from a machine as compared with the amount of work put in? For example, with a block and tackle such as represented in the figure on page 238, how many pounds should you be able to lift by an exertion of a force of 50 pounds? Actually, however, you will be able to lift not more than 60 or 75 per cent of this amount.

In the same way you will find that the work obtained by the use of the inclined plane, cogwheels, etc., is not equal to the amount of work expended. This is due to the fact that there is a certain amount of resistance when one surface slides or rolls over another. This resistance, which is called *friction*, results because the surfaces are not absolutely smooth. Examination with the microscope will show that even the smoothest appearing surface has many small irregularities. Naturally, therefore, when two surfaces rub together, what will happen?

The efficiency of a machine is the ratio of the work done or energy given out to the work or energy put into it. For example, if in the block and tackle which we have considered before, we pull the power rope 6 feet with a force of 50 pounds and are able to lift a maximum weight of 200 pounds 1 foot, then the efficiency of the machine may be stated as follows:

$$\text{Efficiency} = \frac{\text{work done } (200 \times 1)}{\text{work put in } (50 \times 6)} = \frac{200}{300} = \frac{2}{3} = 66\tfrac{2}{3}.$$

After using the pulleys it will be found that they are slightly warmer. What, therefore, has become of energy that does not appear as useful work?

Problem 9. How friction may be reduced.

Experiment. — By means of a spring balance, pull an iron block up an inclined plane. Note the pounds of force necessary. Now put grease or heavy oil on the plane and on the lower side of the block. Note again the force necessary to pull the block up the plane. Conclusion?

Give examples of the use of oil or grease in machines with which you are familiar. Explain why failure to oil the working parts of a machine will cause them to wear out

FIGURE 183.—"SKIDDING" LOGS ON SNOW.
Why cannot this be done if there is no snow?

more rapidly; why screws may be screwed into wood more easily if soap is rubbed on them; why failure of the oil supply of an automobile engine causes the engine to become

overheated; why the wheel on a wagon or automobile will sometimes refuse to turn if it has not been properly oiled. (Note that metal expands when heated.)

Experiment. — By means of a spring balance pull a small box filled with weights or sand up an inclined plane. Note the force required. Now put rollers under the box and again pull it up the same incline. Note the force required.

Can you skate faster with roller skates fitted with ball bearings or with those which have plain bearings? Is it easier to slide a barrel along on its end or to roll it? All automobile and bicycle wheels have roller (Figure 184 *a*) or ball (Figure 184 *b*) bearings. What is your conclusion concerning the friction between surfaces in which one rolls upon the other as compared with the friction between surfaces that slide upon one another? Name all the cases you know where the efficiency of machines is increased by the substitution of rolling friction for sliding friction.

FIGURE 184 *a*. — ROLLER BEARINGS.

FIGURE 184 *b*. — BALL BEARINGS.

Bearings are usually made of different material from that of the axles that rest upon them. This is done because generally the friction between two surfaces of different material is less than that between surfaces of the same material.

Problem 10. Is friction ever useful? — Since we have seen how friction lessens the efficiency of machines which we

use in accomplishing work, we are likely to conclude that friction is one of our greatest enemies, and that our everyday work and the work of the world would be done much better if all friction were eliminated. Let us see if this conclusion is a correct one.

Let us suppose that instead of raising a piano to a high window, we are lowering it from that position; what effect will friction have? What would happen to an automobile going down a mountain side, if the brakes should fail to work? What would happen to an automobile in the traffic of a city, if it had no brakes? It is as important to have the brakes in good working order as to have the engine working well. Brakes do their work by increasing friction.

A train of cars weighs many hundreds of tons. Because of inertia, a large amount of force is necessary to start it. The energy is supplied by the burning of the coal or oil within the engine, but the energy or force is applied between the drive wheels and the track. If the track should be greased, what would happen? How is friction concerned with the starting of the train?

Again, after the train is in motion, inertia tends to keep it in motion: on a level track the engine only needing to furnish sufficient force to overcome the friction between the wheels and the track. If the train is going forty miles an hour, it will be seen that the force necessary to overcome its inertia will be very great. How is this force applied to bring it to a stop? Why is there provision for sprinkling sand on the rails? Why is an automobile apt to skid on a wet or oily pavement?

Compare walking on an icy pavement with walking on a pavement having no ice. Would you be able to walk if there were no friction between your feet and the pave-

ment? Why do baseball players wear spikes on their shoes?

In bringing a vessel alongside a dock, a rope is thrown out and wound several times around a strong post (Figure

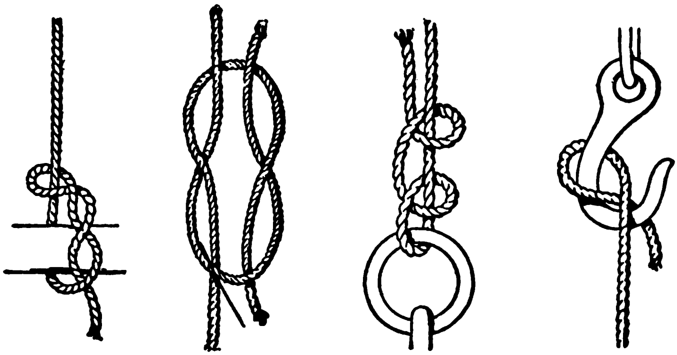


FIGURE 185.

a. TIMBER HITCH.

b. SQUARE OR REEF KNOT. The commonest knot for tying two ropes together. Frequently used in first aid bandaging; Never slips or jams; easy to untie.

c. TWO HALF HITCHES. Useful because they are easily made and will not slip under any strain.

d. BLACKWALL HITCH. Used to secure a rope to a hook.

185 *a, b, c, d*). Suppose the rope and post are so slippery that there is no friction, what will happen? What keeps any knot from slipping? What causes threads in cloth to remain in place?

Lumber is fastened together by nails and screws; what prevents them from dropping out? Endeavor to consider the condition of things if friction did not exist.

Problem 11. Causes of inefficiency of engines. — In engines in which the burning of fuel is the source of energy, there are other losses in addition to that due to friction. Suggest some of the ways in which energy in the form of

heat is lost from a steam engine; also the gasoline engine. It has been estimated that in the steam engine about 95 per cent of the energy of the coal is lost, and that the efficiency of the engine is only about 5 per cent. In the gasoline engine, since no heat escapes in the ashes and smoke and less surface is exposed to be cooled, the loss is considerably less and the efficiency of the engine may be as high as 30 or 35 per cent.

In the oxidation of fuel in the muscles of the human body, only about 25 per cent of the energy is transformed into working energy; 75 per cent of it taking the form of heat. Explain why we become so heated while exercising. Suggest how shivering, when we are cold, may be of value to the body.

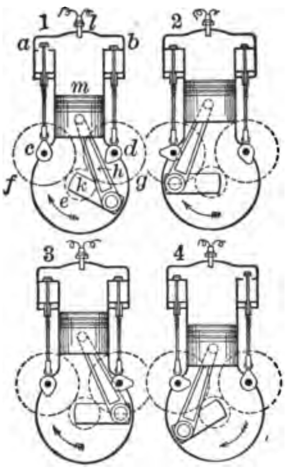


FIGURE 186.—MOVEMENTS OF PISTON IN A FOUR-CYCLE ENGINE.

Problem 12. The working of the gas engine. — The gas engine has become of great importance not only because of its economy of fuel, but also because of its ease of operation and lightness. Its combination of great power with light weight has made possible the marvelous development of the airplane and automobile. You will be interested in looking into the working of the gasoline engine as shown in the motor of an automobile.

The successive positions of the piston may be seen from the examination of the accompanying diagrams.

First or suction stroke. — The mixture of air and gasoline passes into the cylinder. Note that the gasoline is not a liquid but a gas, having become vaporized in the carburetor.

Second or compression stroke. — The mixture of air and gas is compressed.

Third or power stroke. — At the end of the compression stroke, the air and gas mixture is exploded by the spark that passes between the two wires, and the piston is forced downward.

Fourth or exhaust stroke. — The piston passes back into the cylinder, forcing out the gases which remain after the explosion. The piston is now in position for the beginning of the suction stroke again. Note the position of the intake and exhaust valves at each stroke.

Of the four strokes of the piston, how many are power strokes?

As four strokes are necessary to complete the cycle (circle), an engine of this kind is known as a four-stroke cycle engine.

The power developed by the explosion in the cylinder is applied to moving the automobile by having the piston rods connected with the crank shaft, which is made to rotate by the up-and-down stroke of the piston rod. By a series of cogs called *gears*, the power is applied to the rear axle, causing the wheels to turn.

Need for a flywheel. — What causes the engine to run between the times of the power strokes? A one-cylinder engine would not run if a heavy flywheel were not attached to a continuation of the crank shaft. The power stroke sets in motion the flywheel which by its rotation carries the crank shaft around until the piston is in position for the next power stroke.

Advantage of a number of cylinders. — The first automobiles made were equipped with one-cylinder gasoline engines, but now they are fitted with engines having a number of cylinders; four, six, eight, twelve, and in airplane engines

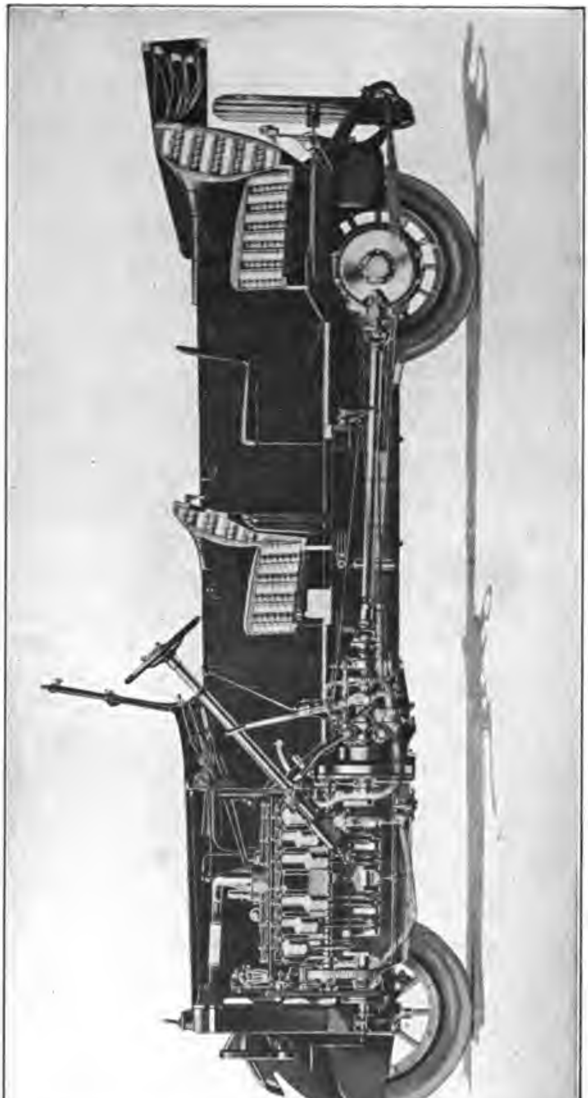


FIGURE 187.—SECTIONAL VIEW OF AN AUTOMOBILE.

an even larger number. By the use of a number of cylinders, the power is more continuously applied, with the result that the engine runs much more steadily.

Explain how a four-cylinder, four-cycle engine would have four times as many power strokes as a one-cylinder engine.

How the spark is furnished. — When an engine is started, the spark is usually furnished by an electric current generated by a battery. However, after the engine has started, it generates its own electricity by means of a *magneto.* This explains how an automobile may be started without the use of batteries by allowing it to coast downhill or by turning the crank rod a number of times, sometimes called "spinning on the magneto." It is evident that the magneto must be equipped with an apparatus for timing the spark, for if the explosion occurs a fraction of a second too soon or too late, the results will be unsatisfactory.

Explain why the engine must be started by hand (by cranking) or by a self-starting apparatus.

Cooling the engine. — As the cylinders become very hot during the explosions, they must be cooled. This is usually done by surrounding the cylinders with a space filled with water. The water circulates through the *radiator* where it is cooled by air drawn through the meshes of the radiator by a fan. Some automobiles are cooled by air without the assistance of water.

As all parts must slide easily in order to avoid loss of power and overheating by friction, there must be a system by which the engine automatically oils itself.

Suggested Individual Projects

1. Plan and carry out a series of demonstrations to illustrate the various uses of levers.
2. Construct a windlass and demonstrate its use to the class.
3. Construct a set of cogwheels by which power is gained at the expense of speed.
4. Construct a set of cogwheels by which speed is gained at the expense of power.
5. Demonstrate the use of cogs in several machines. Calculate the kind and amount of advantage gained.
6. Construct a toy machine in which belts are used.
7. Construct several sets of pulleys and demonstrate their use.
8. Construct an inclined plane and show its value.
9. Work out the different kinds of simple machines used in the construction of the sewing machine or other machines familiar to you.
10. Work out the efficiency of a number of machines.
11. Demonstrate the various kinds of knots described in the *Manual of the Boy Scouts of America.*
12. Make a simple cylinder with piston to illustrate the action of the piston of an automobile cylinder.

Reports

1. How things that were done by hand a hundred years ago are now performed by machines.
2. How the power developed by the automobile engine is transmitted to the drive wheels.

References for Project XXII

1. Great Inventors and Their Inventions, Bachman. American Book Company.
2. Harper's Machinery Book for Boys, Adams. Harper & Bros.
3. Mechanics of Sewing Machines. Singer Sewing Machine Company.
4. Stories of Useful Inventions, S. E. Forman. Century Company.
5. The Story of Agriculture in the United States, Sanford. D. C. Heath & Co.

6. The Story of Iron and Steel, Smith. D. Appleton & Co.

7. The Romance of Modern Mechanism, Williams. J. B. Lippincott Company.

8. Stories of Inventors, Doubleday. Doubleday, Page & Co. (Automobiles.)

9. The Romance of Modern Locomotion, Williams. J. B. Lippincott Company.

10. Historic Inventions, Holland. Geo. W. Jacobs, Philadelphia.

11. The Boy Mechanics. Chicago Popular Mechanics Company.

PROJECT XXIII

ELECTRICITY AND MODERN LIFE

If a man who lived a century ago should visit us, he would be much surprised at the many changes which have occurred since his time. Especially would he be amazed at those inventions which depend upon electrical energy. Electricity was being studied by some of the scientists of his time, but probably none of them had the faintest idea of the practical importance that it would have.

Figure 188. — Grand Central Terminal, New York City, before Electrification.

The first electric motor, a very inefficient one, was constructed in 1838, and it was not until 1871 that really efficient motors and dynamos were used. Electric lighting on a commercial scale was used for the first time in Paris and London in 1877. Think of the many things which this visitor from a previous century would see for the first time. Make a list of the appliances of present day life which make use of electrical energy.

Problem 1. How the electric bell rings. — One of the best methods of beginning the study of the way in which we make use of electrical energy is by an examination of the electric bell, which not only is familiar to us all, but illustrates many rather simple things concerning electricity which have very wide application. You already know a number of facts about the bell and the conditions necessary for its working.

FIGURE 189. — GRAND CENTRAL TERMINAL, NEW YORK CITY, AFTER ELECTRIFICATION.

How is the bell connected with the place from which it may be rung, — for example, the front door? How many wires run to the bell? Are the metal wires bare or covered? Are the wires covered where they are fastened to the bell? Of what metal are the wires made? To ring the bell, what must you do to the push button? This brings together the ends of the two wires so that there is a continuous metal circuit beginning at one side of the bell and ending at the other.

Will the bell ring if the wire is broken at any place? Most of you know that the wires are usually connected with one or more batteries which in some way generate electricity, and that the batteries must occasionally be renewed or replaced by fresh ones. If you have removed the small metal

covering just above or below the bell itself, you have noticed two small spools of wire lying side by side. Each is made of a rod of iron, around which is wound some covered copper wire.

When the current from the batteries passes through this copper wire, it magnetizes (makes a magnet of) the rod of iron. One end of the wire is connected with one of the *binding posts*. At one end of the spools or *coils* is an iron bar called an *armature* held in position by a spring, so that when the circuit is open (that is, when the push button is not pressed down bringing the two ends of the wire into contact) it does not quite touch the iron centers of the spools.

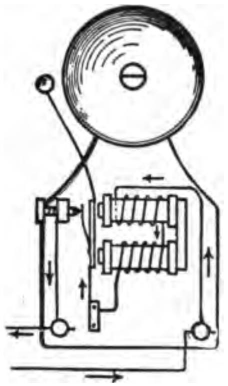


FIGURE 190. — DIRECTION OF CURRENT THROUGH AN ELECTRIC BELL.

From the diagram (Figure 190) note the course taken by the current of electricity in passing from the wire connected with one binding post to the wire connected with the other. Note also that the clapper is connected with the armature. When the circuit is closed, it will be seen that the coils are magnetized and the armature is drawn toward the coils, causing the clapper to strike the bell.

The pulling of the armature toward the coils breaks the circuit. Immediately the coils lose their power to attract the armature, which springs back and closes the circuit. Again the coils are able to attract the armature, and the clapper strikes the bell. This breaking and making of the circuit continues as long as pressure is maintained on the push button.

Problem 2. How magnets are used. — The current of electricity passing through the coil of wire gives the iron rod around which it is wound the power of a magnet. This kind of magnet is temporary, possessing its power only when the current of electricity is passing through the wires. For this reason it is called an *electromagnet* (Figure 191). Electromagnets are used in many electrical devices (Figure 192); among which are telephone, telegraph, and wireless apparatus, ignition sys-

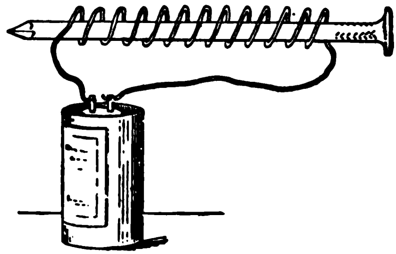


FIGURE 191. — A SIMPLE ELECTROMAGNET.

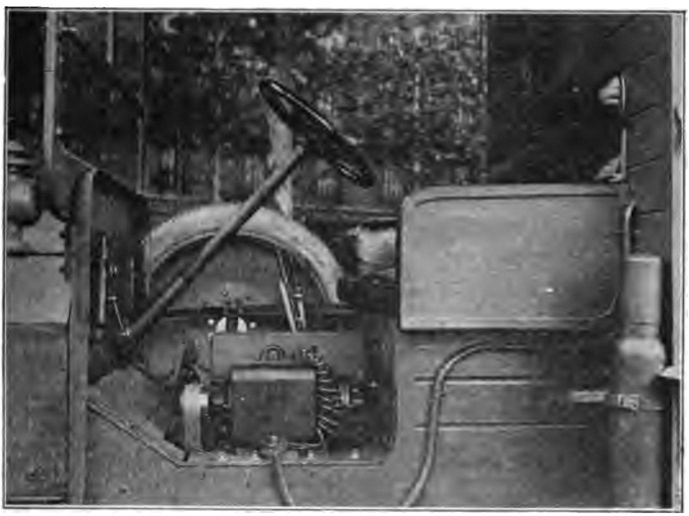


FIGURE 192. — DYNAMO ATTACHED TO AN AMBULANCE.
The current generated by the dynamo produces an electro-magnet which is used to remove pieces of metal from eyes.

tem of automobiles, and in electric motors and dynamos. Large electro-magnets attached to cranes are used to

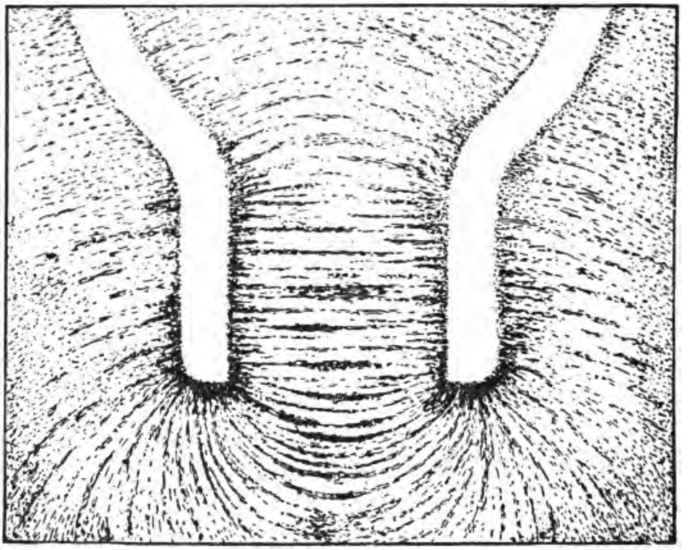


FIGURE 193.—ARRANGEMENT OF IRON FILINGS BETWEEN POLES OF A MAGNET.

lift masses of iron which may be dropped at the desired spot by simply breaking the circuit.

The action of permanent magnets may be observed by experimenting with a common horseshoe or bar magnet.

Experiment. — Place the magnet under a piece of paper over which iron filings have been scattered. Gently tap the paper and observe the position taken by the filings (Figure 193).

Experiment. — Rub a needle along the magnet and move it near some fine iron filings. What has happened to the needle? Suspend the needle horizontally by an untwisted silk thread. Move one end (pole) of the magnet near one end of the needle. Reverse the magnet and approach the same end of the needle with the other pole of the magnet. What is the result? Allow the needle to remain suspended

undisturbed. What position does it take? **The earth itself is a great magnet; one magnetic pole being near the geographic north pole, and the other near the geographic south pole. A magnetic needle, therefore, which swings freely will take an approximate north and south position** (Figure 194). What practical use is made of this fact? **The use of the compass has had a great influence upon the development of navigation.**

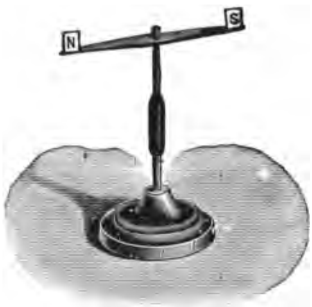


FIGURE 194. — MAGNETIC NEEDLE.

Problem 3. How chemical energy may be changed into electrical energy. — The electrical energy which caused the ringing of the bell was generated in a battery cell by a chemical action. The

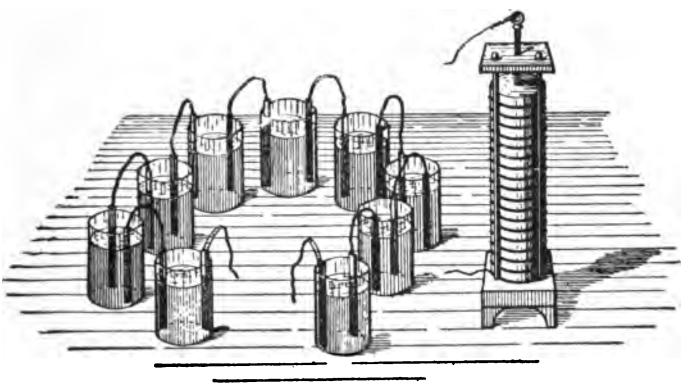


FIGURE 195. — FIRST OF ALL ELECTRIC BATTERIES PREPARED BY VOLTA, A.D. 1800.

At the right is the famous Voltaic pile, consisting of a series of alternate disks of zinc and copper separated by moistened felt. At the left each cell consists of a plate of copper and one of zinc immersed in brine.

simplest form of a cell of this kind, called the *voltaic cell*, was invented in 1800 by Alessandro Volta, a professor in

an Italian University (Figure 195). You can easily make a cell of this kind.

Experiment. — In a jar containing dilute sulphuric acid place two metal plates; one of zinc and the other of copper. If each plate (called an *electrode*) is connected by means of a wire with the binding posts of an electric bell, the bell will ring. After a few minutes the bell ceases to ring although the circuit has not been broken.

An examination of the copper plate will show that it is covered with bubbles of a gas, so that the acid is not able to touch it. The battery is now said to be *polarized*. If the bubbles are rubbed off, the bell will again begin to ring. Various methods have been used to prevent this polarization. One method is illustrated by the *gravity cells*. In this cell, the copper is placed at the bottom of the jar in a solution of copper sulphate (blue vitriol); and the zinc near the top in weak sulphuric acid. The blue vitriol solution is heavier than the acid, and remains at the bottom; hence the name, gravity cell (Figure 196). The blue vitriol or copper sulphate solution prevents the gas (hydrogen) from reaching the copper plate, but it causes copper to separate from the solution and be deposited on the copper plate as a bright layer.

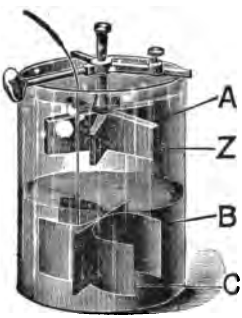


FIGURE 196. — GRAVITY CELL.

A, solution of zinc sulphate. *B*, solution of copper sulphate. *Z*, zinc. *C*, copper.

In the *Daniell cell*, the zinc and sulphuric acid are in a porous cup which is placed in a jar containing the copper and blue vitriol solution (Figure 197). In another form of cell, one electrode is carbon and the other zinc, and the

liquid in which they are immersed is a strong solution of sal ammoniac (ammonium chloride).

FIGURE 197. — DANIELL CELL.

The *dry cell,* which for most purposes is more convenient than any other, is like the last cell mentioned, except that, instead of a jar, a cup or cylinder made of zinc is used as the container, and this forms one electrode (Figure 198). Then instead of sal ammoniac solution being used, a moist paste saturated with sal ammoniac and usually containing manganese dioxide to prevent polarization, is packed between the carbon and this zinc outer wall.

Problem 4. How electricity is measured: volts, amperes, kilowatts. — In all the cells discussed, you have noticed that there has been greater chemical action at the zinc electrode than at the other. This gives rise to what may be called an electrical pressure or *electromotive force* (E. M. F.) and causes a current somewhat as differences in water pressure will produce a current. This current passes from the zinc to the other electrode within the cell, and from the carbon to the zinc electrode through the wire circuit.

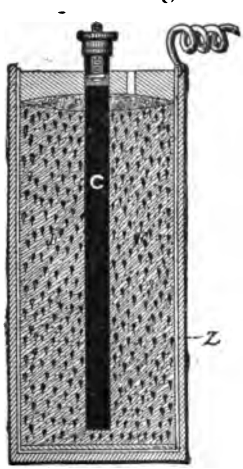


FIGURE 198. — DRY CELL.

The unit of electromotive force is called the *volt.* It is approximately the electromotive force of

the simple voltaic cell. By connecting the several cells *in series*, that is, by connecting the carbon of one cell with the zinc electrode of the next one, etc., the voltage or electromotive force of the battery of cells will be equal to the sum of the electromotive forces of the individual cells. The electrical pressure is measured by an instrument called the *voltmeter*.

The pressure in a water pipe may be very great, but yet there may be very little, if any, flow of water because the faucet opening is quite small. On the other hand, the pressure may be relatively low with a large flow, providing there is nothing to obstruct the current. In the same way, the amount of electricity that passes through a wire depends upon the voltage or pressure, and upon the resistance. The unit of resistance is called an *ohm*, in honor of Georg Ohm, an investigator in electricity, who worked during the early part of the nineteenth century.

The unit of current is called an *ampere*, in honor of another great scientist who was contemporary with Volta and Ohm. The relation of current, electromotive force, and resistance to flow is expressed in Ohm's law:

$$\text{Current} = \frac{\text{electromotive force}}{\text{resistance}} \text{ or Amperes} = \frac{\text{Volts}}{\text{Ohms}} \text{ or Ohms} = \frac{\text{Volts}}{\text{Amperes}}$$

The instrument used to measure the current is called an *ammeter*. A *rheostat* is a device by which the amount of resistance may be controlled. Just as the amount of work done by water power depends upon the pressure and the amount of water, so the work done by an electric current may be determined by multiplying the voltage (pressure) by the amperage (amount of electricity).

The unit of work, called a *watt* in honor of James Watt, is the work done by one ampere having the voltage of 1. Since this is such a small unit, the *kilowatt*, which is equal to 1000 watts, is more often used. Electrical energy is charged for by the *kilowatt hour*, which is the energy furnished by a current providing in one hour one kilowatt of work. A kilowatt hour is equal to about $1\frac{1}{3}$ horsepower (hours), and in New York City costs from $4\frac{1}{2}$ to 7 cents.

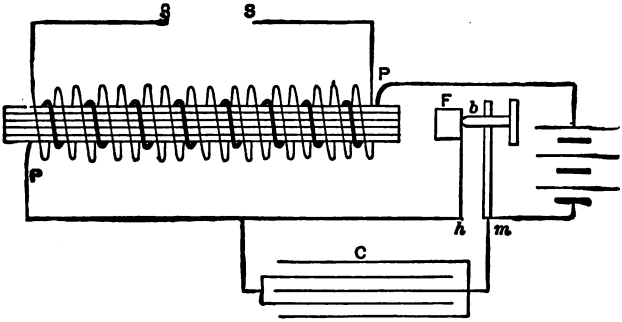


FIGURE 199.—STRUCTURE OF AN INDUCTION COIL.

P, P, primary wire connected with battery. *S, S,* ends of secondary coil between which sparks leap. *F,* iron block which is pulled back when iron core is magnetized, thus breaking the circuit. The iron core is then demagnetized and the spring *h* pulls back the iron block *F* closing the circuit again. Note that there are more turns of the secondary than of the primary.

Problem 5. Use of induction coil in wireless telegraphy and in the production of spark in gasoline engine.—By means of a spark coil, a sufficiently high voltage is produced to cause the current to leap across an air space, forming a spark. It consists of a central iron core, surrounded by a coil of heavy wire called the *primary*, and by a second outside coil, the *secondary* (Figure 199). The primary is connected with a few cells of a battery, and with an interrupter as in the case of the electric bell.

It is by the use of the induction coil that the sparks are produced which explode the gasoline vapor in the cylinders of a gasoline engine, and which send out the electric waves of the wireless telegraph. An induction coil is also an essential part of the transmitting apparatus of a long distance telephone.

In the wireless telegraph, the electric waves act upon the *antenna*, which is made of a number of parallel wires suspended on insulating supports from a mast or tower, and connected by a single wire with a rod on one side of the spark

FIGURE 200. — U. S. ARMY WIRELESS OPERATORS RECEIVING MESSAGES FROM AN AIRPLANE, TOURS, FRANCE.

gap. Electric waves pass out into surrounding space from the antenna and cause similar electric waves in the antenna of the receiving station, which by means of pieces of apparatus called crystal detectors or audion detectors, are made susceptible of being detected by a telephone receiver.

Problem 6. How mechanical energy is changed into electrical energy by the dynamo. — In our discussion of

oxidation of fuel, the use of water power, etc., we understood that heat energy and mechanical energy may be transformed into electrical energy. This is done by the dynamo, a machine complicated in appearance, which, however, in its simplest form is not difficult to understand.

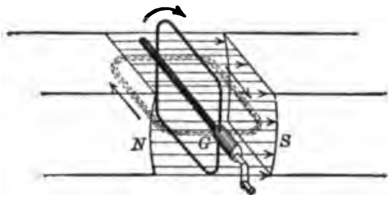


FIGURE 201. — A SIMPLE DYNAMO.
N, north pole of a permanent magnet.
S, south pole of a permanent magnet.
G, point of contact of brushes for carrying current into outside circuit.

You will recall that in the electric bell a current of electricity passing through the coil of wire, wound around a piece of iron, caused the iron to become a magnet. In generating a current of electricity by a dynamo, the reverse occurs. If a coil of wire is rotated continuously between the poles of a strong magnet, an electric current is produced in the coil of wire (Figure 201). The effect of a magnet in producing an electric current in a coil of wire may be shown by the following experiment.

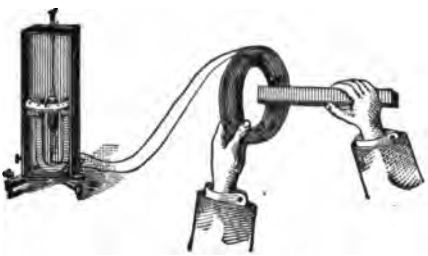


FIGURE 202. — PRINCIPLE OF DYNAMO.
Current produced by thrusting magnet into a coil of wire.

Experiment. — Move a magnet in and out of a coil of wire, the ends of which are attached to a galvanometer (an instrument for detecting currents of electricity (Figure 202). It will be noted that the current is produced only when the magnet is in motion, and that the direction of the current is in one direction when the magnet is pushed into the coil, and in the opposite direction when it is pulled out

The essential parts of a dynamo are (1) a rotary coil (armature), (2) a stationary magnet (field magnet), and (3) a sliding contact device for carrying the current from the armature to the external circuit. The efficiency of the dynamo is increased by the use of electro-magnets as field magnets. Large dynamos may develop electrical power equal to 8000 or 10,000 horse power. For some purposes an alternating current is satisfactory, but for other purposes a continuous current in one direction is necessary. By means of an attachment called a *commutator* (Figure 203), the alternating current of the dynamo may be changed to a direct current.

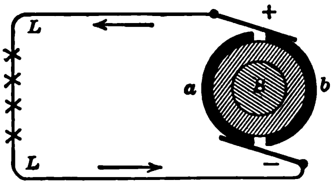


FIGURE 203. — A SIMPLE COMMUTATOR.

a and *b*, two halves of a split tube connected with the two ends of the coil of the armature. + and −, two brushes connected with the external circuit *L*, *L*. *S*, shaft upon which *a* and *b* are mounted.

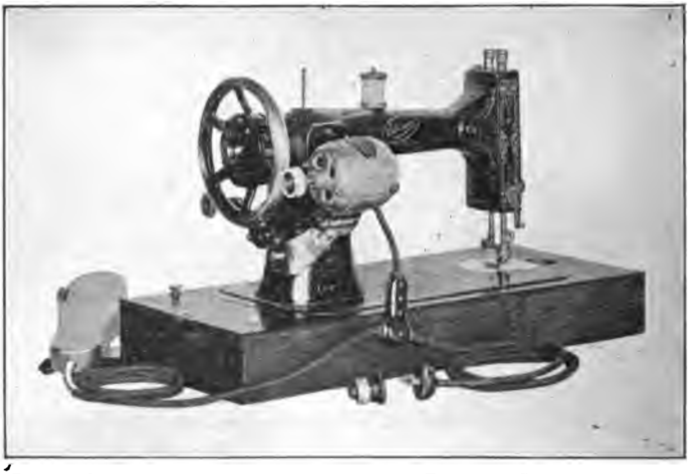


FIGURE 204. — USE OF ELECTRIC MOTOR IN RUNNING SEWING MACHINE.

Problem 7. How electrical energy is changed into mechanical energy by the electric motor. — A motor (Figure 204) by which the electrical energy developed by the dynamo is changed back into mechanical energy is really the reverse of a dynamo; a current passes both into the field magnets and the armature, resulting in a rotation of the armature, which by means of belts, etc., may set machinery in motion. The principle of the motor may be illustrated in the following way.

Experiment. — Suspend a loop or a coil of wire between the poles of a magnet. It will hang in any position in which it is placed. If now a current of electricity is passed through it, the coil, as in the case of the electric bell coil, becomes a magnet and takes a definite position with reference to the field magnets. If the current is reversed, the coil swings around 180°.

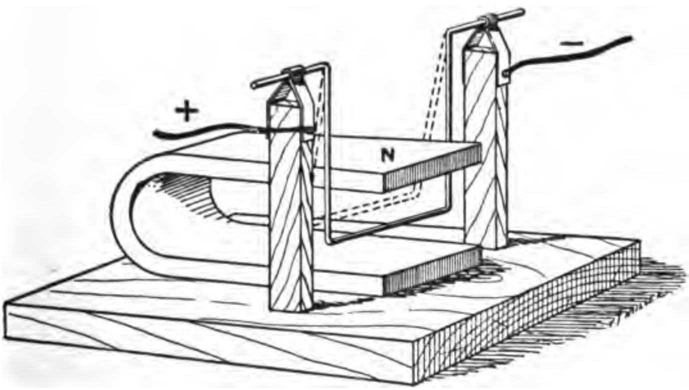


FIGURE 205. — EXPERIMENTAL ILLUSTRATION OF PRINCIPLE OF THE MOTOR.
The dotted line represents the position of the wire as current passes through it.

Figure 205 represents the influence of a magnet upon a wire through which a current of electricity is passing.

It can easily be understood how the armature will con-

tinue its rotation, if the current is reversed at proper intervals of time.

Problem 8. How electroplating and electrotyping are done. — It will be recalled that in the gravity cell, in which there was a solution of copper sulphate, a layer of copper was deposited on the copper electrode. By this process the electrode was really copper-plated. Copper-plate some object such as a piece of tin or nickel as follows.

Experiment. — Suspend in a jar of copper sulphate the object to be plated, and a piece of copper; connect the former with the negative and the latter with the positive terminal (pole) of a battery.

Silver, gold, or nickel plating may be done in a similar way. Name various objects which have been plated with a metal. In each case, state the reason for doing so.

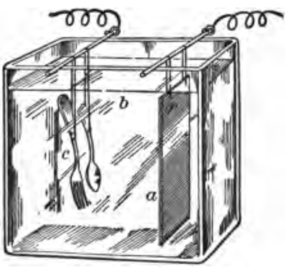


FIGURE 206. — SILVER PLATING. *a*, bar of silver. *b*, solution of a silver compound. *c*, objects to be plated.

Electrotyping. — This power of the electric current to cause a layer of metal to be formed on an object is made use of in printing. This book and nearly all others are printed from electrotype plates. The type is set up and a mold of it is taken in wax. The type may now be taken down and used again. The mold is coated with graphite (a form of carbon) to make it a conductor, and is immersed in a bath of copper sulphate, in which is suspended a piece of pure copper.

A current of electricity is now sent through the liquid from the copper to the graphite-covered wax plate and in this way a layer of copper is deposited on the wax plate. The

wax is replaced then by metal to give strength to the mold. This electrotype plate, which is an exact reproduction of the original page of type, may be conveniently used to print thousands of copies, whereas the type is awkward to handle and soon wears down.

In the printing of newspapers a much quicker method is necessary. A machine called the linotype is used. The operator, by manipulating the keys of a keyboard very much as in using the typewriter, sets the type. The type is then pressed against melted metal, and an imprint made which is used in printing the paper.

The electric current may also be used in refining metals; those refined in this way being the purest obtainable.

FIGURE 207.—AN ELECTROTYPE. Photograph of the plate from which a page of a book is printed.

Problem 9. How heat is produced by electricity. — Name various household appliances in which heat is produced by an electric current. The way in which this is done is illustrated as follows.

Experiment. — Make a circuit of several electric cells and a copper wire of the thickness generally used in making connections. Now replace a small portion of the copper wire with fine iron or German silver wire wound around the bulb of a thermometer. What is the result?

The resistance of small wires to the current of electricity is much greater than the resistance of large wires, and the electrical energy is changed into heat energy. This is similar to the way that mechanical energy when resisted by friction is changed into heat energy. All the electric appliances you have named, such as flatirons, toasters, curling-iron heaters, electric chafing dishes, electric stoves, foot warmers, car heaters, bacteriological incubators and sterilizers, are heated in this way (Figure 208).

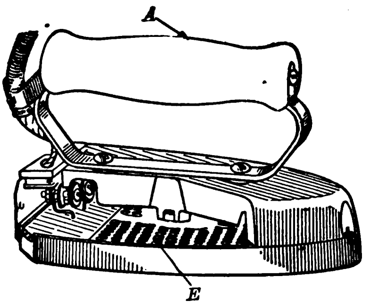


FIGURE 208. — ELECTRIC FLATIRON.
E, wires offering great resistance to electric current. *A*, wooden handle.

Industrially, the changing of electrical energy into heat energy has made possible many important processes. An intense heat (about 3000° C.) is developed in the electric furnace, due to resistance offered to the passage of the current. Some of the uses to which the electric furnace has been put, because of the intense heat generated, are the production of carborundum, the most important abrasive used; artificial graphite, used in the manufacture of electrodes and lubricants; and smelting, the refining of metals.

Problem 10. How electric lights are produced. — Observation of an incandescent electric light lamp will show

that there is within the bulb a very slender filament, which becomes white-hot when the current is turned on. Evidently the condition here is similar to that which we observed in obtaining heat from the electric current. Would you consider the resistance to the current to be greater or less in the lamp than in the wire of a heating device? The wires in an electric stove would melt or become oxidized if raised to such a high temperature. What, therefore, do you consider must have been the great problem in the development of the incandescent lamp?

FIGURE 209.—CARBON FILAMENT LAMP.

The bulb contains no air. What is the advantage of this? Very few substances have been found capable of carrying the current and yet able to remain in a solid form at the temperature necessary for the production of light. For many years specially treated carbon filaments were used (Figure 209). More recently, metallic filaments have very largely replaced the carbon ones; the most satisfactory filament being made of *tungsten* (Figure 210). It uses only about one third as much electricity as the carbon to produce the same amount of light (Figure 211).

FIGURE 210.—TUNGSTEN FILAMENT LAMP.

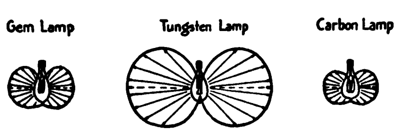


FIGURE 211.—AMOUNT OF LIGHT GIVEN BY DIFFERENT INCANDESCENT LAMPS.

The length of the arrows represents the intensity of light given off in different directions.

The name which has been the most closely associated with the improvement of the incan-

descent lamp, as well as with almost every improvement in the application of electricity, is Thomas A. Edison.

The voltage of the electricity in the main distributing wires is very high. You will find, however, that the electric light bulbs in your house are probably labeled 110 volts. A current of much higher voltage is dangerous to human life. You have probably noticed on some electric light poles iron boxes from which wires pass to the neighboring houses. These boxes are called *transformers*, and in them the voltage is changed from 1100 or 2200 volts to 110 volts. Sometimes transformers are used in the house to still further reduce the voltage of a current used for ringing electric bells, running electric toys, etc.

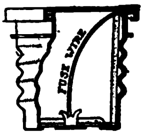


FIGURE 212.— FUSE.

To prevent danger from fire, the wires used in a house must be of sufficiently large size to carry the current without being appreciably heated, and they must be inclosed in metal conduits or tubes in walls and partitions.

An amount of electricity which might prove harmful is prevented from passing into a wire by means of *fuses* (Figure 212), which are pieces of metal of a low melting point inserted in the circuit. When the current becomes too strong the fuse melts and automatically breaks the circuit. Wires must all be carefully insulated; that is, covered with a material which will not conduct an electric current.

FIGURE 213.— POSITION OF CARBONS IN AN ARC LIGHT.

The arc light, which is of very

high candle-power, may be understood from a demonstration of the lamps of a projection lantern. It will be noted that there are two carbons (Figure 213), which are first brought into contact to complete the circuit. When they are pulled apart, the circuit is not broken but the current continues to flow across the space, producing the *arc*. The (+) carbon becomes hollowed out, and the (−) carbon becomes pointed, apparently by the addition of particles of carbon to it. It seems quite clear that particles of carbon jump across the gap between the two carbons.

Problem 11. How the "storage battery" is used. — Storage batteries have come into common use. Most of you will know of some instances of their use. Find out as many examples as you can of the use of storage batteries. The following experiment will help you to understand a storage battery.

Experiment. — Suspend two pieces of lead in a very dilute (1–40) solution of sulphuric acid in a battery jar. Connect the lead plates with a battery of three or more dry cells. Do you notice signs of any activity in the battery jar? After allowing current to pass through the lead plates for about five minutes, disconnect the dry cells.

Connect the wires attached to the lead plates to an electric bell. Result?

From the facts that one of the plates became brown and gas is given off from the plates during the process of charging, what kind of a change do you think is taking place? The electric current in passing through the lead plates and the sulphuric acid causes changes somewhat like the ones we observed in electroplating. The effect is to make these plates unlike each other in a way similar to that in which the zinc plate is unlike the copper plate in the simple voltaic cell. When the two changed lead plates are connected

with an electric bell, the bell rings, showing that the chemical energy which has been derived from electrical energy has now been changed back again into electrical energy.

About 75 per cent of the electrical energy passed into a storage cell may be recovered again as electrical energy.

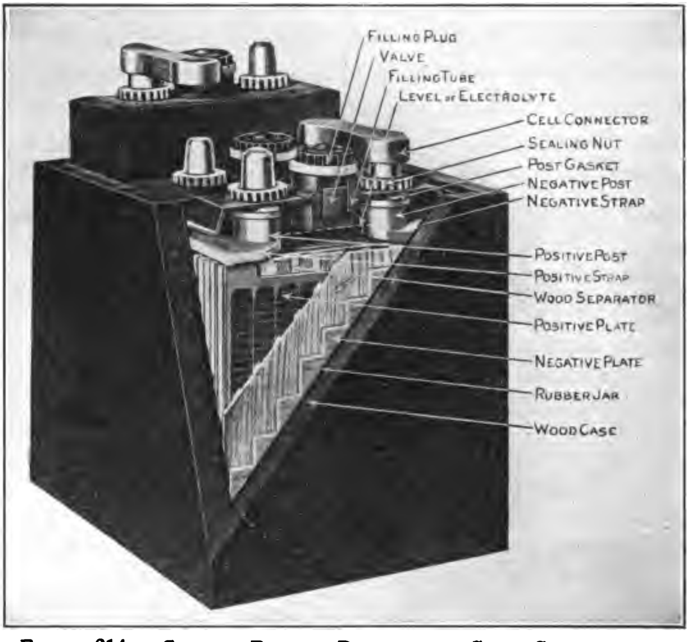


FIGURE 214.—STORAGE BATTERY DISSECTED TO SHOW CONSTRUCTION.

Heat developed during the process of charging and discharging the cell accounts for the loss.

Lighter storage cells have nickel and iron plates, but the principle of their action is the same. Electrical energy is changed into chemical energy which is changed in turn again into electrical energy when the cell is discharged. Commercial storage cells are made of a large number of plates

(Figure 214). All the negative plates are connected with one wire and all the positive plates with another wire. While the voltage remains the same, with the increased surface of plates the amperage is increased.

Problem 12. How lightning is produced. — Lightning is an instantaneous discharge of electricity of high voltage between a cloud and some object on the earth or between two clouds. If on a cold day you scuffle over the carpet and then hold your knuckle to the gas fixture or even to the cheek of another person, a spark will be produced. Because of friction between your feet and the carpet, electricity called *static electricity* has been generated. Since cold, dry air is a poor conductor, the electricity remains upon your body. When, however, your hand is brought so near the gas fixture that the voltage of the electricity is sufficient to cause it to leap through the dry air, the spark results.

In the formation of a storm cloud, large quantities of static electricity are generated and condensed on the drops of moisture. When the voltage becomes sufficiently great, the electricity is discharged to the earth or to a neighboring cloud. Benjamin Franklin's experiment in which he drew lightning from the clouds is a very interesting one. He flew a kite into the thunderclouds, using a string which was a fair conductor of electricity, to which was attached at its lower end a metal key. Near the lower end of this string was a silk cord (a very poor conductor) which he held in his hand. Sparks passed between the key and the ground.

The crackling of the fur of a cat when stroked, and of hair when combed with a rubber comb, especially on a clear cold day; and the tendency of tissue paper, when rubbed, to stick to the wall, are common examples of the manifestations of static electricity resulting from friction.

Suggested Individual Projects

1. Construct an electro-magnet.
2. Construct electric cells of various kinds.
3. Construct a copper- or nickel-plating apparatus and plate a number of objects.
4. Endeavor to rejuvenate a dry electric cell.
5. Use of ammeter and voltmeter in an automobile.
6. Construct an induction coil.
7. Make a model showing how a dynamo works.
8. Make a model showing action of an electric motor.
9. Construct a simple electric heater.
10. Calculate the cost per hour of the different electric lights in your home or in your father's store.

Reports

1. The story of the discovery and development of the electric light.
2. Give a sketch of the life of Thomas A. Edison.
3. Benjamin Franklin and electricity.
4. The making of electroplates from which books are printed.
5. The printing of a newspaper.

References for Project XXIII

1. Farmers' Electrical Handbook. Western Electric Company, New York, 50 cents.
2. The Compass, the Signpost of the World. P. R. Jameson. Taylor Instrument Company, Rochester, N. Y.
3. Benjamin Franklin, P. E. More. Houghton Mifflin Company.
4. Great Inventors and Their Inventions. Bachman. American Book Company. (Edison.)
5. Modern Triumphs, E. M. Tappan, Editor. Houghton Mifflin Company. (Edison and Electric Light.)
6. Wonders of Science. Houghton Mifflin Company. (An Interview with Edison.)
7. Electricity and Its Everyday Uses, J. F. Woodhull. Doubleday, Page & Co.

8. The Story of Great Inventions, E. E. Burns. Harper & Bros. (Electric Furnace.)

9. The Book of Wireless, A. F. Collins. D. Appleton & Co. (Telegraph, Telephone.)

10. Book of Electricity, A. F. Collins. D. Appleton & Co.

11. Harper's Everyday Electricity, Shafer. Harper & Bros.

12. Wonders of Science, Houghton Mifflin Company. (The Making of a Book.)

13. Great Inventions and Discoveries, Piercy. Chas. E. Merrill Company. (Telegraph.)

14. Stories of Inventors, Doubleday. Doubleday, Page & Co. (Telephone.)

15. The Boy's Life of Edison, Meadowcraft. Harper & Bros.

16. Boy's Book of Inventions. Doubleday, Page & Co. (Electric Furnace, Electric Light, etc.)

17. The Wireless Man, Collins. Century Company, Philadelphia.

18. Historic Inventions, Holland. Geo. W. Jacobs, Phila. (Bell, Edison, Marconi.)

19. American Inventions and Inventors, Mowry. Silver, Burdett & Co. (Telegraph, Telephone, etc.)

20. Things a Boy Should Know about Electricity. T. M. St. John, New York.

PROJECT XXIV

RELATION OF LIGHT TO OUR ABILITY TO SEE THINGS

WE have already considered the great source of our light and the ways in which we produce light. Briefly review this. We also understand the importance of light as energy, and its relation to other forms of energy. Briefly review your knowledge of this. In this chapter we shall be concerned chiefly with the relation of light to our ability to see things.

Problem 1. How objects are visible. — Our common experiences prove to us without further experiment that light must be present in order to see objects. Recall experiences which prove this. It is easy to understand how an object which produces light is visible, but how are objects like books, chairs, etc., visible? When light strikes an object, a book for example, some or all of the rays of light are reflected.

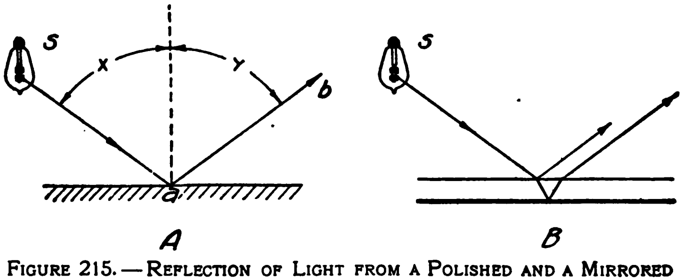


FIGURE 215. — REFLECTION OF LIGHT FROM A POLISHED AND A MIRRORED SURFACE.

Arrows represent the relative intensity of the rays of light.

If the surface of the book were perfectly smooth (Figures 215 and 216), the rays would all be reflected in the same direction, and no rays would reach our eyes unless we were in a certain location (Figure 217). The cover of the book, however, is not so smooth as it appears to be,

FIGURE 216.—REFLECTION OF LIGHT FROM A SMOOTH SURFACE.

and consequently the light rays striking these inequalities are reflected in every direction (Figure 218) in straight lines, so that rays will reach our eyes regardless of our position, providing there is nothing between us and the object to intercept the rays.

The effect of the inequalities may be understood by throwing several tennis balls together upon an irregular surface and noting the directions in which they bounce. The rays of light which pass into the eye from an object form an

image or picture on the sensitive inner coat of the eye, the *retina*, just as such an image or picture is formed on the sensitive plate or film of a camera. In some way which we do not thoroughly understand, nerve fibers carry to the brain information of impressions made by the light on the nerve endings, and we become conscious of the size, color, and shape of the object.

How do you account for the fact that a room may be light although the sun does not shine directly into it?

Problem 2. Cost of artificial lighting of rooms. — Name

FIGURE 217. — HELIOGRAPH.

By means of a mirror light of the sun is reflected to a place many miles distant. Dots and dashes of the telegraph code are produced by a shutter operated by the sender of the message.

the various methods of producing light for the illumination of rooms when sunlight is not available. We are especially concerned with the comparative costs of these different kinds of lights. To determine this, we must be able to measure the intensity of a light. To do this we must know

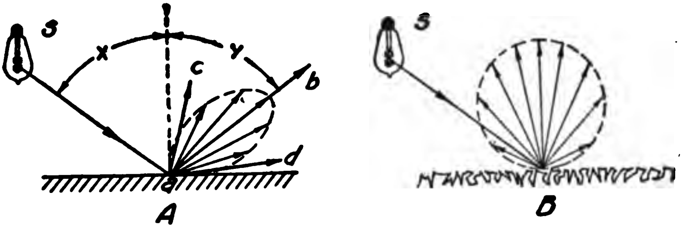


FIGURE 218. — REFLECTION OF LIGHT FROM A SLIGHTLY ROUGH AND A ROUGH SURFACE.

how the intensity of a light decreases as the distance from the light increases. This may be found out by the following experiment.

Experiment. — Darken a room except for one small source of light. Arrange pieces of opaque cardboard respectively 1, 2, and 3 inches square, on supports so that they can be moved away from or toward

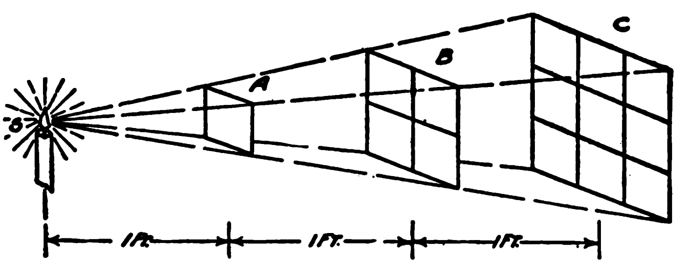


FIGURE 219. — RELATION OF INTENSITY OF ILLUMINATION TO DISTANCE FROM SOURCE OF LIGHT.

Compare the area of *B* and *C* with area of *A*. What is the intensity of light upon one of the squares of *C* as compared with intensity upon *A*?

the source of light. Place the 1-inch screen one foot from the light and place the second screen so that the shadow cast by the first just covers it.

In the same way place the third screen so that it is just covered by the shadow. Measure the distances between the first and second and the second and third screens. What is the relation of these distances

to the distance between the source of light and the first screen (Figure 219)?

If the first screen is removed it is evident that the light striking the second screen is the same that illuminated the first screen. But what is the area of the second screen as compared with the first? What, therefore, will be the intensity or brightness of the light on the second screen as compared with the intensity on the first screen?

In the same way compare the intensity of the light upon the third screen with that on the first screen. What conclusion can you draw now concerning the decrease of brightness or intensity of light as the distance from the source of light increases?

Your conclusion may be stated in the following terms: *The intensity of light is inversely proportional to the square of the distance from the light-giving body.*

This experiment may be modified by substituting for the first screen a larger screen in which is cut an opening one inch square. In this modification of the experiment the light-giving body should be surrounded by an opaque screen in which a small pinhole has been made so that the light comes from a point. Unless the opening is very small the result will not be satisfactory.

The principle which we have discovered in the preceding experiment may be used in the following way to compare the relative light-giving power of two lights.

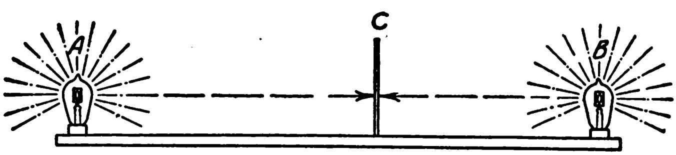


FIGURE 220. — PHOTOMETER.
An apparatus used to measure the comparative light-giving power of two lights.

Experiment. — Place the lights to be tested several feet apart on a table in a room which is otherwise dark. Slide an upright piece of

opaque cardboard along between the lights until no shadow is cast on either side of the cardboard (Figure 220). This means, of course, that there is an equal illumination of each side of the cardboard. Since the intensity of light is inversely proportional to the square of the distance from the light-giving body, the relative power of the two lights may be calculated. If, for example, it is found that one of the lights (a) is 4 times as far from the cardboard as the other (b), then $a : b :: 4^2 : 1^2$, or as 16 : 1.

The standard of measurement of the light-giving power of a light is called a *candle power*. This was originally the light given by a candle made according to certain specifications. At the present time the value of the candle power in the United States is established by a set of standard incandescent lamps maintained in the Bureau of Standards in Washington. Most incandescent lamps have the candle power etched upon them. It can be seen that if the candle power of one light is known the candle power of another lamp may be determined by the experiment above.

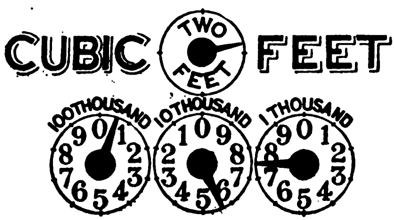


FIGURE 221.—GAS METER READING 5700 FEET.

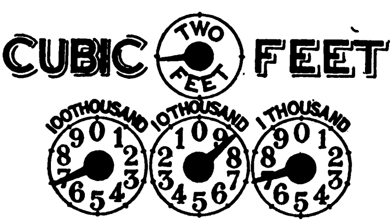


FIGURE 222.—GAS METER READING 68700 FEET.

Knowing the light-giving power of two lamps, it is possible by finding how rapidly the oil or gas (Figures 221 and 222) is consumed or the number of kilowatt hours (Figure 223) of electricity used, and the price charged, to

estimate the cost per candle power of various kinds of lights. The following table (Figure 224) has been worked out, showing the relative cost of producing a certain amount of light. Costs have been based on the following prices: Candles, 12 cents per pound; kerosene, 15 cents per gallon; gas, $1.00 per 1000 feet; and electricity, 10 cents per kilowatt hour.

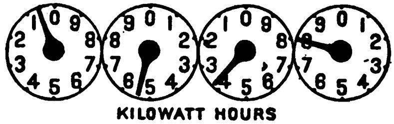


FIGURE 223. — FACE OF A KILOWATT HOUR METER.

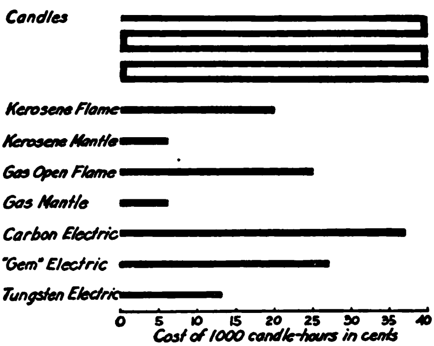


FIGURE 224. — RELATIVE COSTS OF DIFFERENT LIGHTS.

Problem 3. Why shades and reflectors are used. — The effectiveness of the lighting of a room may be increased by the proper use of shades and reflectors. In lighting a room several things must be kept in mind: that strong direct rays of light are injurious to the eyes; that in some

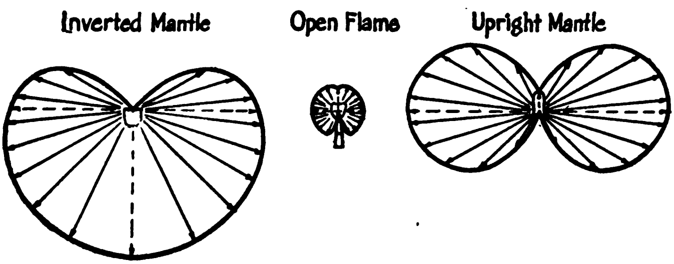


FIGURE 225. — COMPARATIVE AMOUNTS OF LIGHT GIVEN BY AN OPEN GAS FLAME AND A GAS MANTLE.

cases a general illumination of the room is desired; and that in other cases certain parts or objects in the room should be more brilliantly lighted.

Give examples showing when a general illumination is desired; when special parts of the room should be better lighted. All these aims are accomplished by means of the use of shades and reflectors. Can you recall any room that has seemed

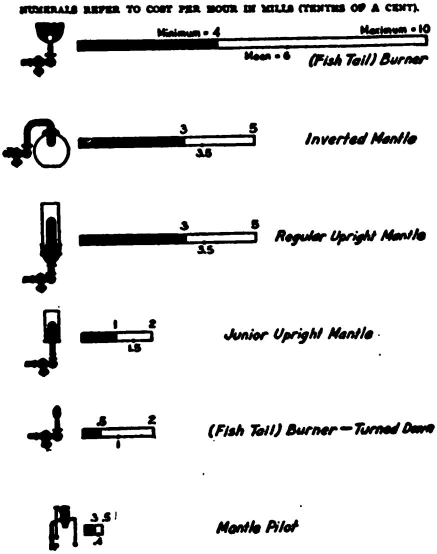


FIGURE 226. — COST PER HOUR OF DIFFERENT GAS LIGHTS.

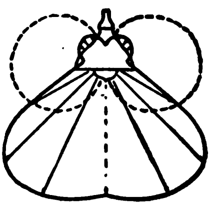


FIGURE 227.

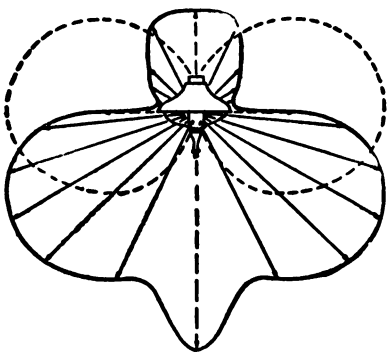


FIGURE 228.

Figures 227 and 228 show how small an amount of light passes upward when lights are shaded.

to be satisfactorily lighted in which there was not some use made of shades or reflectors?

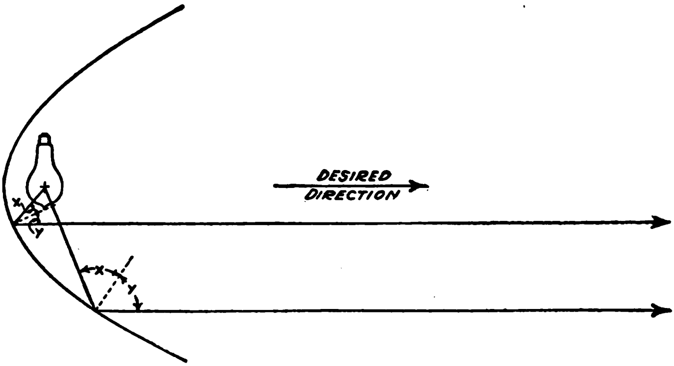


FIGURE 229. — REFLECTION OF LIGHT BY A POLISHED METAL REFLECTOR.

We sometimes hear the terms, *direct* and *indirect* lighting, used. In direct lighting, the rays are reflected in one general

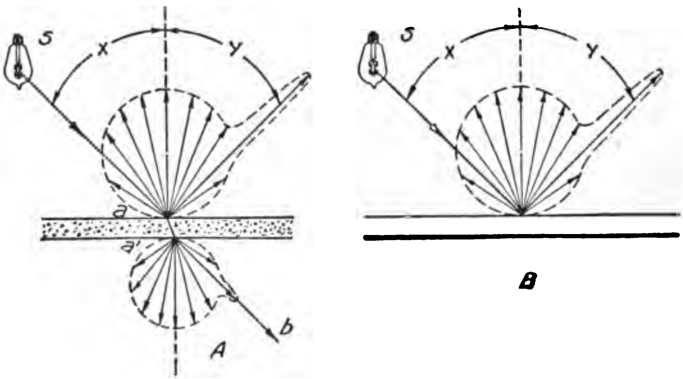


FIGURE 230.
A, reflection and transmission of light by opal glass. *B*, reflection of light by enameled steel.

direction by the use of an opaque reflector Figures 229 and 230 *B*). Individual reading lamps are usually of this type.

By the use of translucent shades which permit some of the rays to pass through, we have what might be called *semi-direct* lighting (Figures 227 and 230 *A*). Many halls and meeting rooms, where a general distribution of light is desired, have opaque or partially opaque bowl reflectors by which the rays of light are directed to the white ceiling which in turn reflects them downward throughout the room. If translucent shades are used, considerable light also passes directly outward and downward from the lamp.

Problem 4. How the color of the wall affects the lighting of a room. — We can best understand the relation of the color of the wall to the lighting of the room by performing a simple experiment.

Experiment. — Obtain or make a pasteboard cylindrical box from four to six inches in diameter and a foot or more in depth. Paste a picture or some printed matter in the bottom. Loosely roll a piece of white paper, slip it into the box as a lining, and look at the picture or printed matter. Remove the white paper and insert a roll of colored paper. Do this successively with wall paper of various colors. What is the effect upon the illumination of the interior of the box?

Make a list of the wall papers in the order of their value for use in rooms that are likely to be dark. Make a list of wall papers in order of their value for use in rooms that are likely to be too light. Compare dirty with clean wall paper and glazed with unglazed paper with respect to their relation to illumination.

You have seen that the color of the walls makes a great difference in the lighting of a room. Dark-colored walls absorb more light, and hence reflect less than light-colored walls. Pure white walls reflect about 80 per cent of the light that strikes them; while dark green, maroon, chocolate brown, or dark blue walls do not reflect more

than about 5 per cent of the light striking them. Smooth walls reflect more light than those which are rough. Dirt upon the walls reduces their power of reflection.

Problem 5. Why objects have different colors. — If we see the various things around us by reflected light, is it not rather surprising that they should have different colors? The light which comes from one book affects the nerve endings in the eye in such a way that it carries a message to the brain which gives us a sensation of red; the light from a book beside it may give us the sensation of green. The light striking the books must be the same, for if we put the red book where the green one was, it still continues to be red. Apparently, therefore, the object from which light is reflected causes a change which gives rise to the color.

Another illustration of the production of color by light is the color seen at sunset and sunrise. What colors have you seen on these occasions? Have you ever seen the colors in water spray when looked at from certain positions, or colors along the edge of broken glass? What are the colors of the rainbow?

These observations all indicate that ordinary light, which we call white light, may be broken up into various colors. The truth of this may be shown by the following experiment.

Experiment. — Darken the room. Place a glass prism in such a position that a beam of sunlight admitted through a small opening will pass through it (Figure 231). What do you observe on the opposite wall?

This experiment shows that white light is really a combination of the colors that are seen in the rainbow. We are now ready to understand why not all objects are white. When light strikes the wall, for example, a portion of it is

absorbed, and a portion of it is reflected. You have noticed that some walls reflect more light than others. The cover of a green book reflects only that part of the white light which gives us the sensation of green; a red book, on the other hand, absorbs all the light except the part which gives us the sensation of red.

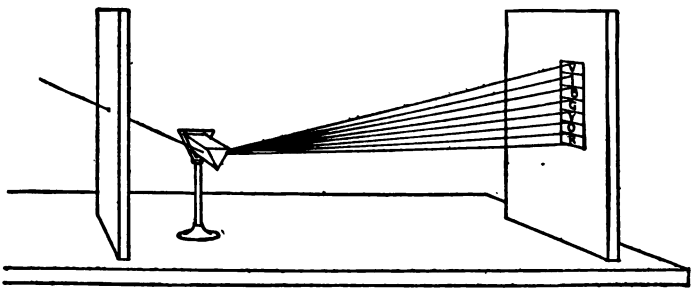


FIGURE 231.—BREAKING UP OF LIGHT IN PASSING THROUGH A PRISM.

The white paper of this page reflects almost all of the light which strikes it, but the black letters absorb practically all the light which strikes them. A piece of red glass allows only red rays to pass through; all of the others being absorbed or in some cases partially reflected.

Since the absorbed light is changed into heat, explain why light-colored clothing is more comfortable in the summer and in the tropics, and dark-colored clothing is preferred for winter wear. Explain why the colors of objects may not be the same in artificial light as in sunlight. This can be shown in an extreme form by comparing the colors of a number of pieces of paper or cloth when observed first by sunlight, and then by a candle in which is held a glass rod which has been dipped in common salt solution.

Problem 6. What is the cause of the colors of sunset

and sunrise and of the blueness of the sky?—What are the chief colors of sunset and sunrise? In the experiment, in which by means of the prism you broke up white light into the different colors, which colors were bent least, and which most, from the original path of the light ray? The atmosphere, with its particles of moisture and dust, has some power of separating the colors which make white light. Explain now why the reds and oranges are seen at sunset and sunrise. Why are they not seen at midday?

Keeping in mind again the rays that are bent most by the prism, and the fact that the atmosphere has some power to separate the rays which compose sunlight, how do you account for the blueness of the sky? This can be illustrated to some extent by putting a few drops of milk into a jar of water and looking through the jar at a light. Explain why the sunsets are apt to be most brilliant in late summer and fall. During the great forest fires in the northern United States and in Canada, the sun appeared orange or even red in color. Explain.

Problem 7. Why eyeglasses are used by some persons. —You all know people who without glasses must hold a book very close to the eyes in reading. These nearsighted persons have trouble in seeing distinctly anything which is more than a few feet from them. On the other hand, you may have friends who are farsighted; who can read signs at a greater distance than you can, but who have trouble in reading a book or newspaper held at the ordinary reading distance from the eye. Nearly all persons, as they grow older, become farsighted; and you will notice that many begin to wear glasses at about the age of forty or even much younger.

By the use of glasses both the nearsighted and the far-

sighted are enabled to see as well as those who are not troubled by these eye defects. To understand how glasses are able to bring about this change, it is necessary to know how the rays of light act in entering the eye.

Sub-problem 1. How a picture or image is formed in the eye. — The following diagram (Figure 232) represents the con-

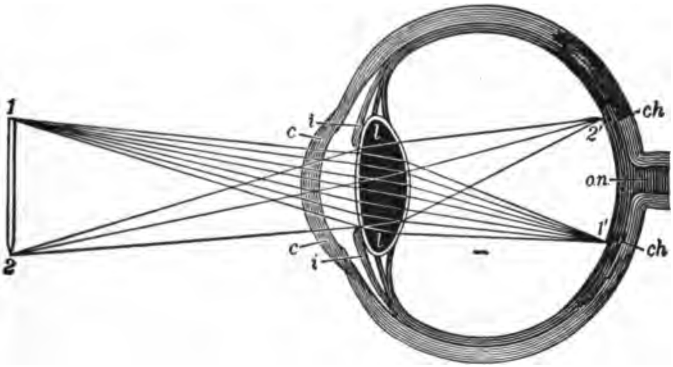


FIGURE 232. — RAYS OF LIGHT PASSING INTO THE EYE.

1, 2, extreme points of the object. *1', 2',* focus of rays upon sensitive layer of eye (retina). *c,* cornea. *i,* iris. *ch,* choroid (colored coat of eyeball). *l,* crystalline lens. *o.n,* optic nerve, passing from eye to brain.

dition in the normal eye. It will be noticed that the rays of light are bent as they strike the curved surface of the *cornea,* and again as they pass through the *crystalline lens,* finally coming to a focus on the nervous layer, the *retina,* lining the back of the eye cavity. This is the same process that takes place in a camera when the rays of light coming from an object are bent by the lens of the camera and focused on the sensitive film or plate.

Sub-problem 2. How light is bent in passing from one substance into another. — The ability of a lens to bend the rays of light is very well illustrated by a burning glass, with which the parallel rays of the sun may be focused on one point, producing enough heat there to burn a piece of paper.

The effect of a lens upon a ray of light may be understood from the following diagram (Figure 233).

Light may be considered to be made of a column of transverse vibrations. These are slowed as they pass into a denser substance like glass. You can easily understand how the column will be bent if the glass is entered at an angle. In the same way, as the ray of light passes from the glass into the air again, it will be bent. This bending of the rays of light (Figure 234), in passing from one substance into another, called *refraction*, explains the fact that a stick, projecting at an angle from the water, appears to be bent at the point where it leaves the water.

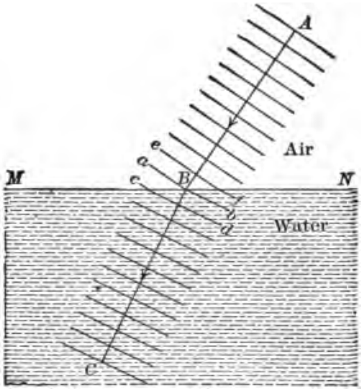


FIGURE 233. — A DIAGRAM SHOWING HOW A LIGHT RAY MAY BE BENT.

Sub-problem 3. How the eye is able to focus on near and distant objects. — You will wonder how we can focus the eye upon a distant object, and then without any appreciable effort, focus it upon something near. The power of accommodation may be illustrated as follows.

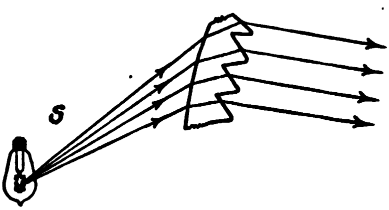


FIGURE 234. — BENDING OF RAYS OF LIGHT BY GROOVED GLASS.

Experiment. — Hold a pencil before your eyes and read the label on it. How does a picture on the opposite side of the room appear? Still keeping the pencil in the same position, look at the picture. How does the pencil appear now?

In a camera, such a change in focus is brought about by moving the lens closer to or farther from the sensitive film. In the case of the eye, it is of course impossible to change the distance between the lens and the sensitive inner coat of the eye, the retina. The same result, however, is accomplished by changing the shape of the lens. This is done by muscles which are connected with a tough membrane or ligament inclosing the lens. When near objects are looked at, these muscles contract, pulling forward the edges of the ligament which are attached to the coat of the eye. Because of its elas-

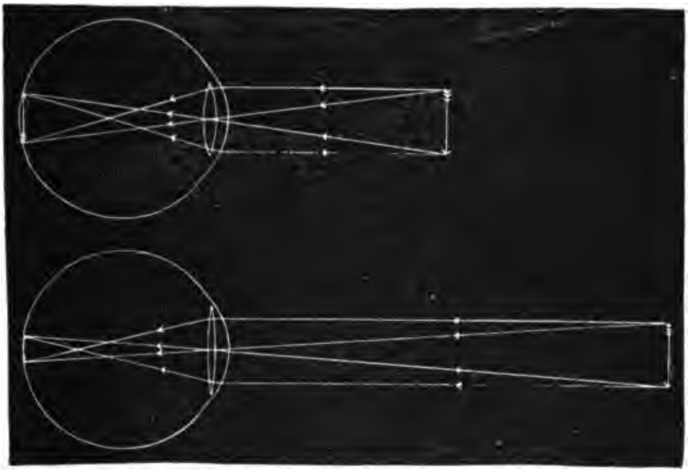


FIGURE 235. — CHANGE OF FOCUS OF EYE.
Upper figure, eye focused on a near object. Lower figure, eye focused on a distant object.

ticity, the lens then becomes more convex and the image of the object is focused upon the retina (Figure 235).

● **Sub-problem 4. Cause and correction of farsightedness and nearsightedness.** — As a person becomes older, the lens loses its elasticity and it becomes impossible for him to see near objects distinctly, although his power of seeing things at

some distance remains unimpaired. You can easily see how the use of slightly convex glasses will do the work that the flat lens of his eye will not do, enabling him to see, for example, the print of a book as well as before the lens began to lose its elasticity.

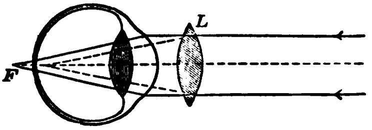


FIGURE 236. — FARSIGHTEDNESS AND ITS CORRECTION.
L, lens. *F*, focus.

Farsightedness, not the result of age, is usually due to the fact that the eyeball is too short. An examination of the diagram (Figure 236) will show that a distinct image of near objects cannot be formed on the retina. This condition can be corrected by the use of convex glasses. Explain.

Nearsightedness, on the other hand, is usually caused by the eyeball being too long. In this case the image of an object held at the normal reading distance, or at any distance farther away, is formed in front of instead of on the retina. This condition can be corrected by the use of concave eyeglasses (Figure 237). Explain.

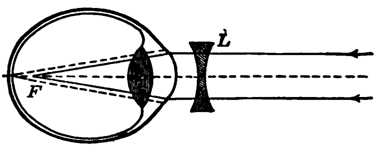


FIGURE 237. — NEARSIGHTEDNESS AND ITS CORRECTION.

Sub-problem 5. What is astigmatism and how is it corrected? — Many persons who are neither farsighted nor nearsighted must wear glasses or suffer from headaches. This is caused by a defect of the eye called *astigmatism*, which results from the unequal curvature of the cornea (the front of the eyeball). What effect will this have upon the bending of the different rays of light that enter the eye? The glasses for these eyes are curved in such a way that the defects of the cornea are counteracted. If glasses are not worn, the ciliary muscle in its effort to bring about a condition which will result in a clearer image is overworked and eyestrain and headache result.

If you are troubled with eyestrain or headache after using the eyes for some time, have your eyes examined at once by a competent oculist or optometrist. Eyestrain results in both discomfort and lessened efficiency. Frequently headaches, nervousness, and other troubles are relieved as by magic when eyestrain has been removed by the use of proper glasses.

Problem 8. Advantage of having two eyes.

Experiment. — Close one eye and attempt to put the cap on a fountain pen held at arm's length. With one eye still closed, attempt to put a pencil into a hole which it just fits. Try the same things with both eyes open. Hold a book several feet in front of you, with its edge toward you. Look at it first with both eyes open, then alternately with one eye closed and then the other. What are the results?

Evidently each eye forms an image of an object viewed from a slightly different angle. The effect of this is to give us a sense of the thickness of objects, and also of their distance from us. The brain is able to interpret the angle formed by the rays of light coming from the object to the eyes, and consequently we are conscious that one object is farther from us than another. Pictures viewed with an instrument called the *stereoscope* give an impression of depth and distance such as an ordinary photograph fails to give. The two pictures which are mounted together have been taken with a double camera, the lenses of which are the same distance apart as the human eyes.

Problem 9. How eyes may be injured. — It must be remembered that although the eyes are in perfect condition they may be abused, and eyestrain with its accompanying troubles will result. Too continuous focusing upon close work tires the eye. Occasionally looking away at some distant object for a few moments rests the eye to a surprising degree.

Reading by a dim light causes overwork of the muscles of the iris in their effort to enlarge the pupil to admit all the light possible. The image is indistinct on the retina, causing one to hold the page closer to the eye, throwing an excessive amount of work upon the ciliary muscle. One is very apt to abuse the eye by reading in the evening as the light is fading; the eye gradually accommodating itself to the lessening light until a condition of excessive strain is reached.

Too strong a light is almost as bad. The muscles of the iris make a brave effort to narrow the pupil as much as possible to shut out the excessive light which is tiring the nerve endings of the retina.

A flickering or changing in the intensity of the light coming to the eye causes constant changes in the eye. From this point of view discuss the best kind of light to be used in reading.

Reading on street cars and trains, especially at night, often results in headache and eyestrain. Explain.

The reading of books and papers printed in fine type or on glossy paper is highly objectionable; especially is small type objectionable in books used by young persons.

Serious eye diseases have been contracted by those who have rubbed their eyes with their fingers after having been holding to a strap in a street car or after having touched door knobs or railings which have been handled by many persons. Explain.

Problem 10. How a lens makes objects appear larger. — The action of a reading glass or a simple lens is illustrated by the following figure.

It will be noticed that the rays of light come to the eye at the same angle as though they came from a much larger

object, and the brain thus interprets the image formed on the retina.

In the case of the compound microscope, the rays of light before reaching the eye become crossed, and also enter the eye at a much wider angle; hence, the object is highly magnified and appears upside down. All instruments such

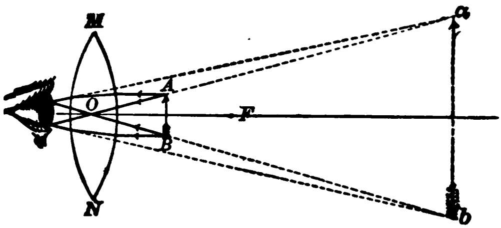


FIGURE 238. — MAGNIFYING GLASS.

as the telescope, opera glasses, and projection lanterns, which are used to give us a magnified appearance of an object, depend on lenses which cause the light coming from that object to enter the eye at a much wider angle than if the light came *directly* from it. The brain, in every case, interprets the image on the retina as though these wide-angled rays were coming directly from the object.

Problem 11. How motion pictures are produced. — The moving picture machine which has come to play such an important part in our lives in giving us recreation and instruction is really a projection lantern in which the pictures to be projected are very small, and developed on a roll of transparent celluloid or a similar substance.

The pictures were taken by a camera in which the photographic film was drawn along by a revolving mechanism, thus getting a succession of exposures of moving objects, each exposure differing slightly from the succeeding one,

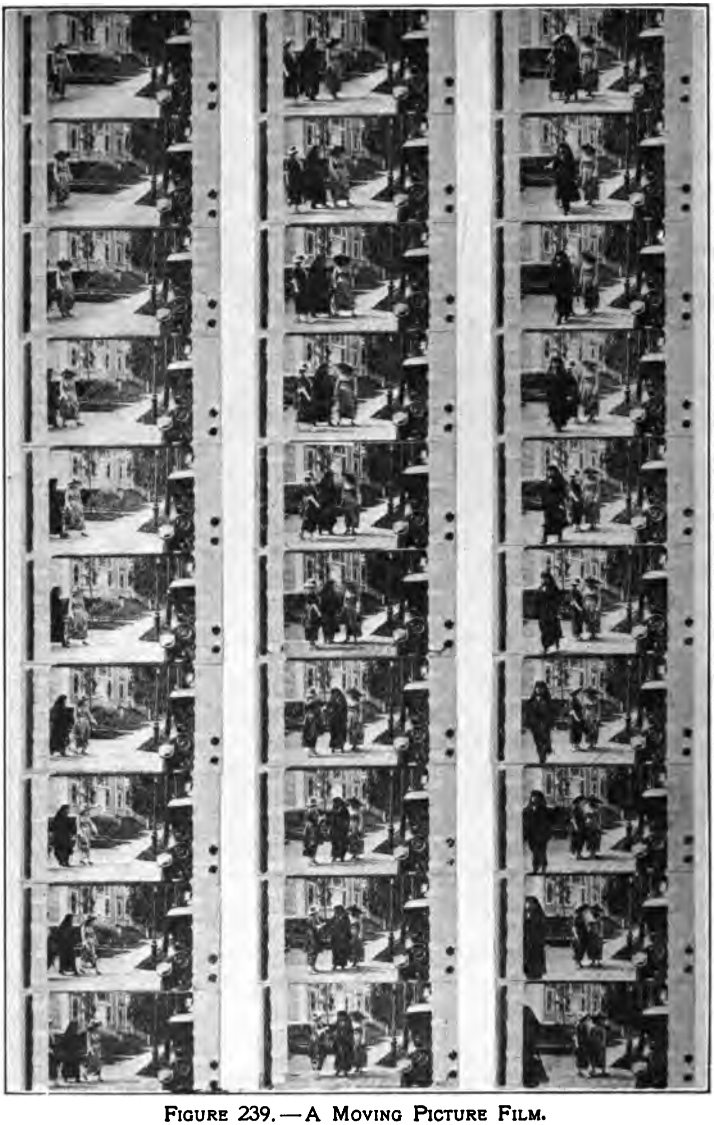


FIGURE 239. — A MOVING PICTURE FILM.

as the movement progresses. By a mechanism similar to that used in taking them, the successive pictures are thrown upon the screen. However, we do not see them as separate pictures, but as *one*, in which the motions of the original subject are reproduced.

The way in which a succession of pictures appears as one continuous picture is well illustrated by the appearance of the spokes of the wheels of a rapidly moving automobile. Do you see each individual spoke? A lantern swung rapidly in a circle is seen as a circle of light. It is evident that the image of an object does not disappear immediately upon the disappearance of the object.

Problem 12. How light effects may guide us in the selection of clothing. — It is not only by the use of lenses that our sense of sight may be deceived. Have you ever noticed that one's feet look larger when white shoes are worn, that stout people look stouter when dressed in white, and that a house once white, which has been painted a dark color, appears to have become smaller in size?

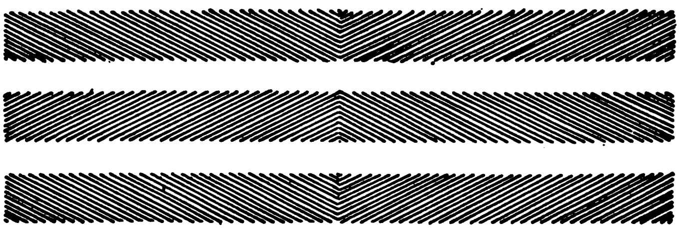


FIGURE 240.
The three systems of lines are equally distant from one another at all points. Do they appear so?

Certain arrangements of lines also deceive us. A stout person appears stouter when he wears clothes which have horizontal stripes, and a thin person appears thinner when

he wears clothes which have vertical stripes. The way in which lines deceive us is illustrated by the preceding figure.

Endeavor to explain the following:

1. Why ground glass or glass with an irregular surface is used in office partitions.

2. Why concave mirrors are used behind headlights of locomotives, trolley cars, etc.

3. Why undimmed automobile headlights are not usually permitted.

4. Why corrugated glass is used in automobile headlights.

5. Why a piece of glass will cast a shadow.

6. The presence of a wavy appearance over a hot radiator or stove, or over a dry road on a hot day.

7. Why colored glasses are frequently worn at the seashore and by motorists.

8. Why it is more difficult to see objects when you first go out at night than later.

9. Why it is difficult to see when you enter a brilliantly lighted room after having been in the dark.

10. Why the inside of a camera is painted black.

11. Why a cake of ice is transparent, and a block of snow is not.

Suggested Individual Projects

1. Determine the relative candle power of the lights in your home and the cost per candle power.

2. Experiments to show the effect of color of walls upon the illumination of a room. (Suggestion. Use long narrow boxes with differently colored walls.)

3. Experiments to show that sunlight may be broken up into rays of light of various colors, and that rays of light of various colors may be combined to form white light.

4. Demonstration of the power of cloth of different colors to absorb light, and change it into heat.

5. Experiments to show the action of convex lenses in correction of farsightedness.

6. Demonstration of how objects are made to appear larger by the use of a lens or reading glass.

7. Demonstration of the focusing of a camera.

8. Demonstration of a motion picture machine.

9. Demonstration of how we may be deceived as to the size and shape of objects by the arrangement of black and white portions.

Reports

1. Various ways in which eyes may be injured, and care that must be taken for their protection.

2. The lighting of factories or office buildings.

References for Project XXIV

1. Stories of Inventors, Doubleday. Doubleday, Page & Co. (How Moving Pictures Came to Be.)

2. Wonders of Science. Houghton Mifflin Company. (Making Moving Pictures.)

3. The American Boys' Handy Book, Beard. Scribners. (Telescopes.)

4. Historic Inventions, Holland. Geo. W. Jacobs, Philadelphia. (Galileo and the Telescope.)

5. American Inventions and Inventors, Mowry. Silver, Burdett & Co. (Torches, Candles, Kerosene, Gas, Electric Lights.)

PROJECT XXV

IMPORTANCE OF HEAT TO US

THE production of heat and its relation to other forms of energy have already been considered. Briefly review your knowledge of these matters. Some of the ways in which problems of heat affect our everyday life have been discussed, but there still remain some cases which need further attention.

Problem 1. How a thermos bottle keeps hot liquids hot and cold liquids cold.

Experiment. — Fill one of two thermos bottles with hot water; fill the other with cold water. Set them side by side together with two ordinary bottles filled respectively with hot and cold water. Examine after two or three hours. Results? Conclusion?

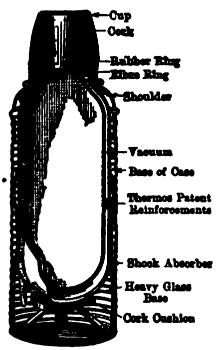


FIGURE 241. — THERMOS BOTTLE.

An explanation of the structure of the thermos bottle (Figure 241) will help us to understand its ability to keep hot things hot and cold things cold.

The space between the two bottles is a vacuum; the air having been pumped from it during the process of manufacture of the bottle. Evidently this vacuum in some way prevents the cooling or warming of the contents. We can understand this better if we realize that coldness is only a lack of heat,

and that a body cools because heat escapes from it. It becomes warm because heat is absorbed. What is your conclusion as to the ability of heat to pass through a vacuum? A vacuum is called a poor conductor of heat. The polished inner surface of the thermos bottle also helps in preventing a loss of heat, since heat will not pass as readily from a highly polished surface as from a dull surface.

Problem 2. How food may be cooked in a fireless cooker. — Food which has already been heated to the boiling point when placed in a fireless cooker continues to cook although no additional heat is applied. State some of the advantages of such an apparatus. It consists of two boxes of wood or metal, one inside of the other, separated by an air space filled with excelsior, sawdust, newspapers, hay, or glass wool which prevents the circulation of air (Figure 242). What are your conclusions concerning the power of still air and the substances mentioned to conduct heat?

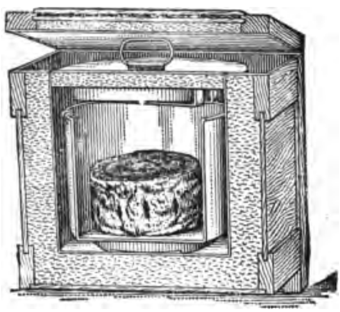


FIGURE 242. — FIRELESS COOKER.

Refrigerator walls are similar in their construction to the walls of a fireless cooker. The space between the walls is usually filled with charcoal.

What is the chief use of clothing in winter? What kind is usually worn then? Explain why loosely woven, woolen clothing is warmer than that which is tightly woven? Why are fur coats so warm? In the summer linen is the coolest material to wear, but any thin, tightly woven, light-colored clothing is comfortable. Explain.

Problem 3. What substances are good and what are poor conductors of heat.

Experiment. — Place in a cup of hot water a silver spoon and a tin or plated spoon. After a few minutes touch the handle of each. Result? Conclusion?

Experiment. — Fill a test tube with water in which has been placed a piece of ice weighted by having wire wrapped around it. Heat the test tube near the top. Result? Conclusion?

Recall your experiences on a cold morning of stepping on a bare wood floor; on a carpet; on paper; or on a tile or stone floor. What are your conclusions as to the power of these different substances to conduct heat?

These observations are sufficient to show you that substances differ very much in their power of conducting heat. The metals may all be classed as good conductors. They may be ranked in the following order:

1. Silver
2. Copper
3. Aluminum
4. Brass
5. Zinc
6. Tin
7. Iron
8. German Silver
9. Mercury

Substances which are medium conductors of heat are:

1. Rock
2. Ice
3. Porcelain
4. Tiling
5. Glass
6. Water
7. Plaster

Poor conductors of heat are:

1. Wood
2. Asbestos
3. Paper
4. Cork
5. Wool
6. Feathers
7. Air

Explain the following:

1. Why birds ruffle up their feathers on a cold day.
2. Why a light-weight feather or down coverlet keeps one so warm.
3. Why heat pipes in basements are frequently covered with asbestos, and mats of this material are used under hot dishes at the table.
4. Why asbestos is fastened to the wall behind a stove.
5. Why newspapers folded under the coat will protect one from becoming chilled on a very cold day.
6. Why the thermos bottle is stoppered with cork.
7. Why the water in deep holes in a lake remains cold during the hottest part of summer.
8. Why iron is better than brick or porcelain for stoves.
9. Why bakers' ovens are sometimes inclosed in brick.
10. Why tea-kettles frequently have wooden handles.
11. Why oven door handles are usually made of coiled wire.
12. Why dead air spaces are left between the walls of a building.
13. Why building paper is placed in the wall of a wooden house.
14. Why the outer vessel of an ice cream freezer is made of wood.
15. Why farmers who plant wheat in the fall of the year are glad to have much snow in winter.
16. Why the ticket choppers at the elevated and subway stations keep a wooden box beneath their feet in cold weather.
17. Why ice is packed in sawdust.
18. Why on a very cold morning outdoors the fingers will freeze to the metal head of an ax but not to the wooden handle.

19. Why iron is a good material for steam or hot water radiators.

20. Why a loosely fitting overcoat is warmer than one which fits tightly.

Problem 4. How houses are heated. — Houses may be heated by stoves or fireplaces which are located in all or several rooms. Most modern houses, however, are heated by furnaces, located in the basement. What are the advantages of this? Are there any disadvantages? The heat produced by oxidation of fuel in the furnace is distributed to the various parts of the house by hot air pipes or by pipes carrying steam or hot water.

Electrical companies are now producing heaters in which electrical energy is changed into heat energy. These are especially valuable when only a small amount of heat is needed as in spring and fall. How are trolley cars heated?

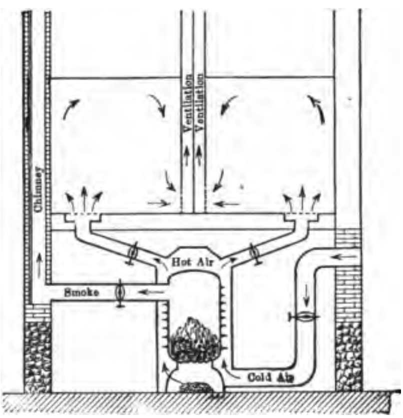


FIGURE 243. — HOUSE HEATED BY HOT AIR.

Sub-problem 1. How houses are heated by hot air. — A hot air furnace (Figure 243) is essentially a large stove around which is a metal jacket through which the air passes to be heated. What causes the air to pass through the pipes into the rooms above? What should be the size of the intake pipes as compared with the size of the pipes carrying air from the furnace? In order that a fresh supply of air may enter a room, there must be an opportunity for the air already there to escape. How

may this be provided for? Hot air furnaces sometimes fail to heat satisfactorily the rooms of a house on the side against which a strong wind is blowing. What is the explanation of this fact?

Some hot air furnaces not only have an intake pipe which receives air directly from outside, but also a pipe which carries air from the first floor back to be heated again. Do you think such an arrangement is good or bad? Explain your answer.

Do you think that hot air heating would be a good method of heating large apartment houses? Why?

The extreme heat of the firebox may cause a warping and cracking of the iron plates of its walls. Explain why gas from the burning coal sometimes comes up through the hot air pipes. This is not usually the case when the damper in the flue is so arranged that the draft is not interfered with. Explain.

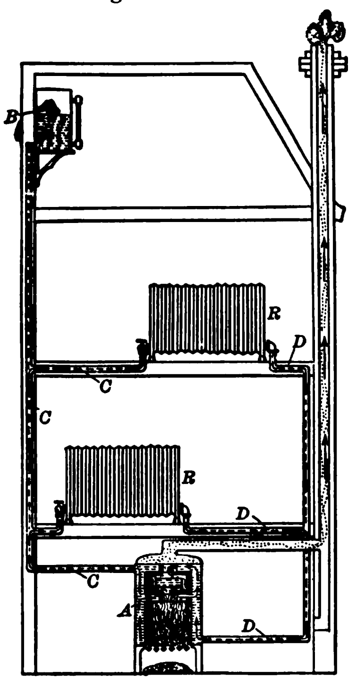


FIGURE 244. — HOUSE HEATED BY HOT WATER.

In what direction is water moving in pipe *C*? in *D*? Why is the tank *B* in the attic necessary?

Sub-problem 2. How houses are heated by hot water (Figure 244). — What causes the water to rise? (Water expands when heated.) Why is it necessary to have the tank in the attic? Must the pipes be full of water? Why? What precautions must be taken if the house is left unoccupied in the winter? The radiator (R), just as a stove, heats a room in two ways; by

radiation, the giving out of heat directly, and by setting up air currents as was discussed in the study of ventilation.

Sub-problem 3. How houses are heated by steam. — In a steam heating plant, steam instead of water passes through the pipe into the radiator. This steam in the radiator con-

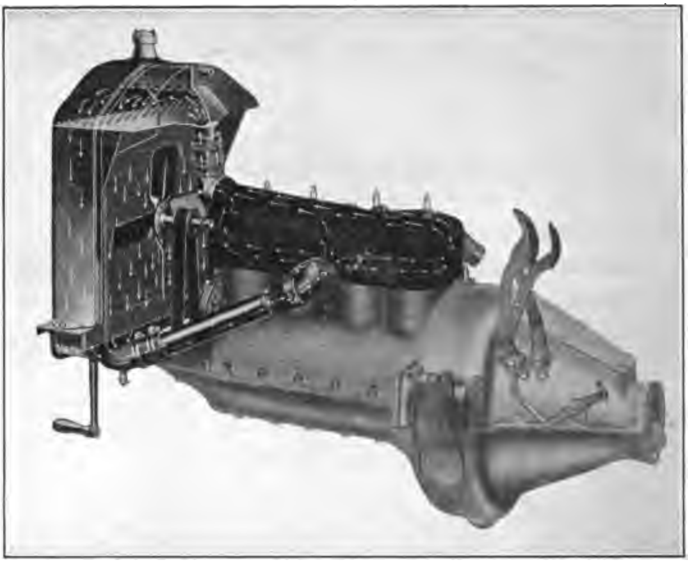


FIGURE 245. — CIRCULATION OF WATER, IN THE RADIATOR AND AROUND THE CYLINDERS OF AN AUTOMOBILE.

The reasons for the circulation of water here are the same as in the pipes and boiler of a hot water heating plant.

denses into water. How does this fact affect the heating of the room? Should the boiler of a steam heating plant be filled with water? Why? Explain the need for the safety valve of the boiler. Explain why on days when only a small amount of heat is needed in the house, steam heat is not so satisfactory as either hot air or hot water heat. Explain why rooms heated

by steam cool off much more rapidly after the fire is shut down at night than rooms heated by hot water.

Explain why in all furnaces the opening of the door below the firebox makes the fire burn better, and why the opening of the coal door checks the fire.

Suggested Individual Projects

1. Make a fireless cooker.
2. Find out the value of different kinds of clothing in preventing the escape of heat from the body. (Suggestion. Cover bottles containing hot water with various combinations of cloth, and observe how soon the water becomes cool.)
3. Determine by experiments the power of different substances to conduct heat.
4. Study the plan of the heating system of your house and make a diagram of it. Explain the reason for the arrangement and the use of various devices.

Reports

Describe the methods of heating houses in different countries, including the kinds of fuel used.

References for Project XXV

1. The Fireless Cooker. Farmers' Bulletin No. 771 U. S. Department of Agriculture.
2. Shelter and Clothing, Kinne and Cooley. Macmillan Company.
3. The Thermometer and Its Family Tree. Taylor Instrument Company, Rochester, N. Y. 10¢.
4. Chemistry of Common Things, Brownlee, Fuller, and others. Allyn and Bacon

UNIT V

RELATION OF SOIL AND PLANT LIFE TO EVERYDAY ACTIVITIES

PROJECT XXVI

HOW SOIL IS MADE

We have already seen how plant life is essential to animal life upon the earth. Without plant life therefore, there could be no human life upon the earth. Explain. In this unit we shall consider projects and problems concerned with the production of plants.

The working out of these projects and the solution of the problems that arise will in many cases help us to solve important problems of animal and human life.

Since the growth of plants is dependent on soil it is evident that we must consider the projects how soil is formed and how it is related to plants. Other projects will naturally be how plants and animals make use of the manufactured food in their growth, how plants produce seed, how better plants and animals are produced, and how plants are protected from harmful insects.

It is known that, if we go back far enough in the world's history, there was once a time when there was no soil. The whole surface of the earth was rock, just as we find the earth's crust if we dig down through the soil. An examination of soil may give us some hints which will help us to understand how it has been formed.

Problem 1. Of what is soil composed?—Examine a handful of dry soil. Do you find any particles of sand in it? What is sand? Examine a very small amount of it with a magnifying glass or microscope. What do you find? Sometimes soils have so many small pieces of rock that they are called *gravelly* soils or *sandy* soils. What do you suspect is the origin of the sand or gravel? What is the color of soil? Where have you ever seen soil that is very dark in color? Can you suggest a possible explanation for this color?

Experiment.—Heat some soil from a flower pot in a crucible or in a test tube if you have no crucible. What change in color appears first? Of what does the odor that is given off remind you? What change in color occurs after continued heating? The material which remains after continued burning is called *mineral matter*. From your observations what do you consider to be the composition of the soil, and from what do you think it has been formed?

FIGURE 246.—RELATIVE SIZE OF SOIL PARTICLES (all highly magnified). From left to right: clay, silt, sand, gravel.

Plants cannot grow unless air and water are present in the soil. A good soil, therefore, consists of decomposed rock material, 60 to 95 per cent of its weight, together with

humus, bacteria, air, and moisture. The materials which make up soils may be classed as follows (Figure 246):

(*a*) Humus, or vegetable mold.

(*b*) Clay, made up of finely powdered rock. The particles are less than one ten-thousandth of an inch in diameter. When dry, clay is powdery; when wet, it is sticky.

(*c*) Silt, consisting of particles somewhat coarser than clay. When moist it becomes a soft mud and usually crumbles when it is dry.

(*d*) Sand, made of rock fragments.

(*e*) Gravel, composed of large pieces of rock fragments.

Ordinary soils are usually made up of a mixture of clay,

FIGURE 247. — DISINTEGRATION OF ROCK.
Limestone ledge breaking up and forming soil.

sand, silt, and humus. Since moisture is so necessary to plants, the power of a soil to take up and hold water is a very important characteristic of it.

Problem 2. Evidence that soil is now being formed. — Apparently a portion of the soil has been formed from rock.

If this is so, then there should be indications that such a change is going on at the present time. An examination of the side of a railroad cut will usually show gradations from solid rock, through partially disintegrated rock, to well-formed soil. The accompanying picture (Figure 247) shows rocks of various sizes which have been broken off from the great mass of rock. Old marble gravestones with their rounded edges and more or less indistinct lettering are indications that rock may be worn away. These evidences coupled with the fact that pebbles and small fragments of rocks are found in soils indicate that the process of soil making is still going on.


FIGURE 248. — RUGGED MOUNTAINS SHOWING THE EFFECT OF WEATHERING.

Problem 3. How soil has been produced by weathering. — Some of the agencies that change rock into soil can easily be understood. Break a rock, and compare the broken surface with the surface of the rock which has been exposed to the weather. What is your conclusion?

The oxygen of the air may act upon some of the minerals of the rocks causing a change which results in their crumbling.

This is similar to the action of oxygen in causing the rusting of iron. Carbon dioxide dissolved in water is one of the most efficient agents in the breaking down of rocks. It is the action of carbon dioxide in water which has produced the great caves such as Luray Cave in Virginia, Mammoth Cave in Kentucky, and Wyandotte Cave in Indiana, as well as hundreds of smaller ones in various parts of the country where limestone is the common rock. This action can be shown by passing carbon dioxide through water containing a small amount of finely powdered marble.

FIGURE 249.—WEATHERED ROCK AT BASE OF A CLIFF.

What do you think might be the effect upon some rock of alternate heating and cooling caused by the temperature changes of day and night?

Experiment.—Heat a glass tube and plunge it into cold water. What happens? The cracking of the rocks by this means exposes more surface for the action of the weather.

What will happen in cold weather to the water which is in the crevices of the rock? What effect will this have upon the rock? This can be illustrated by exposing to a freezing temperature a tightly stoppered test tube filled with water. The force due to the expansion of water when it changes into ice causes the bursting

of water pipes and the ruin of automobile radiators, if cars are permitted to remain in unheated garages in very cold weather without removal of the water. (This latter may be prevented by adding to the water in the radiator some substance, alcohol for example, which has a lower freezing point.)

FIGURE 250. — ROCK BEING SPLIT BY THE GROWTH OF A TREE.

The great masses of broken rock at the foot of cliffs (Figure 249), as at the base of the Palisades along the Hudson River, are caused very largely by the final breaking off of pieces of rock by the expansion of freezing water which has gotten into the crevices formed by temperature changes. Roots of trees growing in the crevices of rocks also assist in the further splitting of the rocks (Figures 250 and 251).

Problem 4. How soil has been produced by water and wind erosion. — *Water erosion.* — The fragments of rock, produced by the processes mentioned above, are carried along by the swiftly moving water of rivulets and streams. What will be the effect upon the bottom of such streams?

What will be the effect upon the fragments themselves? What is the shape of pebbles and rocks found in a stream? Why? Explain how the valleys of streams have been cut down through the rock. This action of water carrying fragments of rock is called *erosion* (Figure 252). It is exactly similar to the way in which a grindstone is able to sharpen tools; both the grindstone and the metal of the tool are worn away. As the streams become less swift much of the material is deposited, so that soil is constantly being eroded from the more elevated regions and deposited in the lowlands.

FIGURE 251. — BEECH TREE GROWING ON ROCKS.
The roots penetrate into crevices and by their growth split the rocks.

Wind erosion. — In some parts of the world considerable erosion is done by wind carrying sand in the same way that a sand blast is used in etching glass or in cleaning the surface of a stone building. Wind, however, as an agent in the formation of soil is of very little importance in comparison with those already mentioned.

Problem 5. How most of the soil of northern United States has been produced. — In the northern part of our country, pebbles and rocks of all sizes, unlike the solid rock bed of that region, are frequently found imbedded in the soil (Figure 253). Evidently the soil and rocks of those regions

have not been carried there by water, since the rocks are scattered indiscriminately in the fine soil (clay). Explain

FIGURE 252. — WATER EROSION.
Gravel and rock have been eroded from the higher land and carried down by water.

FIGURE 253. — SOIL DEPOSITED BY A GLACIER.
Note the irregularly shaped boulders.

the reason for this conclusion. On examination many of the rocks are found to have scratches on them (Figure 254). Also if the soil is removed, the surface of the country rock will be found to have deep parallel scratches and grooves.

Many thousands of years ago, a great sheet of ice, called a *glacier,* covered the northern part of the United States (Figure 255). As it moved southward, its immense weight broke off fragments of rock which rubbed along the bottom of the glacier and ground up the rocky bed into a finely powdered

FIGURE 254.—ROCK SHOWING GLACIAL SCRATCHES.

soil (clay) leaving great scratches and grooves. The clay and the boulders, or rocks, became thoroughly mixed in the ice. As the glacier reached its southern extent, it melted and the material in it was deposited there as a series of ridges of hills called a *terminal moraine* (Figure 257).

As the glacial period gradually passed, the glacier was unable to push farther south and as a result a series of these moraines have been formed. When the entire ice sheet

melted, the rock and soil carried by it was left wherever it happened to be. As some parts of the glacier carried a large quantity of material and other parts only a small amount,

FIGURE 255.—EXTENT OF ICE SHEET DURING GLACIAL PERIOD.

a layer of rock and soil of unequal thickness was deposited over all the northern parts of the country. The depressions became filled with water and thus the large number of the lakes of these northern states is accounted for.

Problem 6. How soil has been produced by decay of organic matter. — Plants gain a foothold in the soil formed by the decomposition of rock material and, by their own decay and that of animals which live upon them, add to the soil that part of it which causes it to blacken when

FIGURE 256. — A GLACIER.
Glacier flowing down side of Mt. Robson, British Columbia.

burned. This *organic* part of the soil, or *humus* (Figure 258), is of special importance in giving it the proper texture and increased power of holding water. It is also the principal source of nitrogen which is so necessary for plant growth. If you will recall your study of bacteria, you will remember that they are necessary in soils in order to decompose the vegetable and animal matter so that this material may be used again in the growth of plants.

FIGURE 257.—FRONT OF A GLACIER, MT. RAINIER NATIONAL PARK.
Notice the broken rock which was carried down and deposited when the glacier extended somewhat farther into the valley.

FIGURE 258.—FORMATION OF HUMUS.
Vertical section showing forest floor, humus, soil, and roots.

Suggested Individual Projects

1. Collect and put into test tubes specimens of different kinds of soils, including rock and vegetable material which has partially changed into soil.

Reports

1. Evidences in the United States of the glacial period.
2. Description of a glacier.
3. Character of the soil in different parts of your state.

References for Project XXVI

1. Glaciers of North America, J. C. Russell. Ginn & Co.
2. Soils; Their Properties and Management, T. L. Lyon. Macmillan Company.
3. Agronomy, Clute. Ginn & Co.
4. Story of Agriculture in the United States, A. H. Sanford. D. C. Heath & Co.
5. Essentials of Agriculture, H. W. Waters. Ginn & Co.
6. The Land We Live In, O. W. Price. Small, Maynard & Co.
7. Earth and Sky Every Child Should Know, J. E. Rogers. Doubleday, Page & Co.
8. The United States, J. O. Winston. D. C. Heath & Co. (The Great Glacier and Its Effect.)
9. Wonders of Science. Houghton Mifflin Company.
10. Farm Science, W. J. Spellman. World Book Company.
11. Elementary Agriculture, James S. Grim. Allyn and Bacon.

PROJECT XXVII

RELATION OF SOIL TO PLANTS

SINCE the amount of moisture in the soil has a great effect upon the growth of plants one important problem is: how the water-holding power of the soil may be increased. As the project is further analyzed it will be seen that other problems will be those concerned with what plants take from the soil, how these substances may be returned to the soil, how materials are taken from the soil and what the plant does with this material.

Problem 1. How the water-holding power of the soil may be increased. — We all know from observation that the growth of plants depends upon their being able to get sufficient water from the soil. How does grass appear during a prolonged dry period in summer? How may lawns and parks be kept green during such a time? We may water a small garden by the use of a hose, but such a means of supplying water to a large field is impossible. Therefore, any method by which the water-holding power of soil may be improved is very important.

The water which is taken from the soil by plants may have two sources. It may be from water which has recently fallen as rain or it may be from water which has come up through the soil from below. A hole dug in the soil during dry weather will show that the upper part of the soil is dry and that the lower part is moist. If you lift either a board or a stone which has been undisturbed for a considerable time, what is the condition of the soil beneath it? What is

the condition of the soil under a layer of leaves or straw which has been lying in one place for a long time?

During dry weather lay a board on freshly cultivated earth in the garden, and in a few days compare the appearance of the surrounding soil with that under the board. All of these observations indicate that the water which is coming from below is escaping by evaporation at the surface and that the loss may be prevented by a covering of some kind. Sometimes such a covering is provided by a layer

FIGURE 259.—VACANT LOT GARDEN.
Give two reasons for hoeing a garden.

of leaves called a *leaf mulch*. But usually such a method cannot be employed very extensively. It has been found that hoeing (Figure 259) or "cultivating" by making a mulch of dry soil prevents to a great extent this escape of water at the surface. This is because the small capillary spaces through which the water has been coming from

below are broken up. One of the reasons, therefore, for frequent hoeing of a garden or cultivating of a field of corn is to prevent the loss of moisture from the surface of the soil.

The power of different kinds of soils to absorb water from below may be illustrated by the following experiment.

Experiment. — Over the bottom of each of four or five glass tubes having a diameter of one or two inches, tie a piece of cheesecloth (Figure 260). Fill the different tubes with the following kinds of soil: coarse sand, fine sand, loam, and clay. Place the bottoms of the tubes in a vessel of water, and support them so that they will stand upright. After a day examine the tubes and draw conclusions.

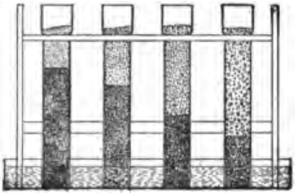


FIGURE 260. — ABSORPTION OF WATER BY SOILS.
From left to right: loam, clay, fine sand, coarse sand.

The finer the soil the smaller are the openings through which the water passes. How does this experiment help you to explain the effectiveness of the loose soil mulch? How does it explain the fact that seeds will grow better if the earth is pushed down firmly around them?

The power of soils to hold the rain which falls upon them is shown by the following experiment.

Experiment. — Into four funnels in each of which has been placed filter paper, put equal amounts of different soils: coarse sand, fine sand, loam, and clay. Pour into the funnels equal amounts of water. Catch the water that runs through in measuring glasses. After pouring the water through several times, note the amount of water that runs through each and draw your conclusions as to the conditions which make soils good holders of water. Suggest how the ability of the soil of a garden to hold moisture may be increased.

Problem 2. What plants take from the soil. — Chemical analysis of plants and experiments in their culture indicate

that the following ten elements are necessary for their growth: Carbon, hydrogen, oxygen, nitrogen, potassium, magnesium, calcium, iron, sulphur, and phosphorus. In our study of the making of starch and wood by plants, we have already discovered from what source the plant gets its carbon, hydrogen, and oxygen. Review and explain. All the other elements must come from the soil.

Fortunately, the soil usually contains all of these with the exception of three, in such quantities that there is not much danger of them being exhausted. The three which are likely to be lacking are nitrogen, potassium, and phosphorus. These frequently have to be added to the soil in some way.

Problem 3. How nitrogen may be given to the soil. — Nitrogen is found largely in the organic part of the soil, and consequently the addition of plant and animal material will increase the stock of nitrogen. One form of organic matter put upon the soil is horse manure. In some parts of the country, fish which are useless for food are spread over the fields. It is said that the early American explorers found that the Indians placed a fish in each hill of corn.

Waste from slaughter houses; guano, the excrement of countless generations of sea birds; cottonseed meal; linseed meal, etc., are useful sources of nitrogen. The nitrogen in none of these plant or animal substances can be used by the growing plant until the bacteria in the soil cause them to decay.

Nitrate of soda, of which there are great deposits in the rainless regions of Chili, and sulphate of ammonia, which is a by-product of the manufacture of gas, are other valuable sources of nitrogen.

It has been known for a very long time that a crop of clover seems to enrich the soil. As a result of this knowledge,

most farmers after using a field for various crops for several years plant clover in it. In order to understand this, we must first know that the nitrogen of the air cannot be used directly by plants. Plants may fail to grow because of nitrogen starvation, although the crevices in the soil around their roots and the space around their leaves are filled with air, four fifths of which is nitrogen. Clover and related plants, such as peas, beans, alfalfa, etc., have small enlargements on their roots which are not possessed by others. These enlargements contain a certain kind of bacteria which have the power to convert some of the nitrogen of the air into a form which can be used by the plant.

Several methods have been discovered by which the nitrogen of the air has been made to combine with some other substance, forming a compound which may be used for plant growth. The need for nitrogen compounds during the war, chiefly for making explosives, has caused large factories to be built for the production of nitrogen compounds. Now that the need for explosives has largely disappeared, the products of these factories may be used to supply nitrogen compounds needed for the growth of plants.

Problem 4. How potassium and phosphorus are supplied to the soil. — Both of these elements are found in the mineral part of soil. They are usually in an insoluble form which cannot be taken up by plants. The action of weather and of the acids produced by decay of vegetable and animal matter in the soil change the insoluble potassium and phosphorus compounds into soluble substances which can be taken up by plants.

Decaying animal and plant matter not only helps to make the potassium and phosphorus compounds already in the

mineral part of the soil usable, but as they themselves contain compounds of these two elements their addition increases the supply. Wood ashes spread upon the soil improve the growth of plants largely because of the great amount of potassium which they contain.

The chief source, however, of potassium fertilizers has been the great deposits of Stassfurt, Germany. During the war the United States together with all other countries faced a potassium famine which threatened to lessen crop production. At the time the war ended, methods for obtaining potassium from rocks holding it in an unusable form were being perfected. It had also been found that considerable quantities could be obtained from kelp or seaweed, which is very abundant on some parts of the Pacific coast. So, if the war had continued, we could have had a supply of potassium to meet all our needs.

One of the sources of phosphorus fertilizers is organic matter such as slaughter house waste and fish scraps; bone meal is especially valuable since a large part of the mineral material of bones consists of a compound of phosphorus. Other important sources of phosphorus fertilizers are phosphate rocks, and slag from steel mills. The phosphate rock is found in many of the southern and western states. The slag is obtained in the process of removing phosphorus from iron in the making of steel.

Problem 5. How plants remove needed materials from the soil.—Review what we have already learned concerning how the roots of plants are fitted to take in water. Since the dissolved mineral substances in the soil are taken in with the water, the adaptations of the roots for taking in water are also adaptations for taking in the needed mineral substances.

If the ashes of different kinds of plants growing side by side are analyzed by a chemist, it is found that the various mineral substances are not present in the same relative amounts. For example, clover will contain many times as much lime or calcium as wheat; while wheat, on the other hand, may contain as much as ten or fifteen times as much silica as clover. Apparently, the plant is able to select the materials which it needs. This is known as *selective absorption.* The explanation seems to be that if the living matter of the plant does not take a certain kind of mineral substance out of the water which has passed into the plant through the wall of the root hair, then the sap or water in the root hair becomes saturated with that special kind of mineral substance and no more will pass through the wall of the root hair. If, however, the plant uses a particular mineral substance, then it is constantly being taken out of the sap and more comes through the wall of the root hair to replace that which has been taken out by the living matter.

Clover, for example, in its growth is continually building lime material into plant substance; and as a result, more lime comes through the membrane of the root hair. Wheat does not use nearly so much lime; and accordingly, very little need come through the root hair to replace the amount taken out by the living matter of the plant.

Problem 6. What plants do with material taken from the soil.—You have already learned how in the green leaves of the plant the carbon dioxide of the air and the water from the soil are made into starch. As a result of the action of the living material of the plant, the starch may be made into cell walls, and into fat or oil. There are always associated with the living matter of the plant more complex

substances called *proteins*. These contain not only carbon, hydrogen, and oxygen as starch does, but also nitrogen, phosphorus, iron, etc., which have been taken from the soil. The proteins are necessary for the growth of new living matter.

Some of the elements, in addition to being necessary constituents of living matter and of the food materials formed in plants, have special duties to perform. Some seem to neutralize acids formed in the plant; others are necessary constituents of the coloring matter of plants; while still others give firmness to the woody substance of the plant.

Suggested Individual Projects

1. Use different kinds of fertilizer in your garden and record the results.
2. Experiments to show the water-retaining power of different kinds of soil.

Reports

1. Obtaining potassium from seaweed.
2. Records of the amount of various mineral materials taken from soil by some of the standard crops.

References for Project XXVII

1. Soils; Their Properties and Management, T. L. Lyon. Macmillan Company.
2. Agronomy, Clute. Ginn & Co.
3. Story of Agriculture in the United States, A. H. Sanford. D. C. Heath & Co.
4. Essentials of Agriculture, H. W. Waters. Ginn & Co.
5. The Land We Live In, O. W. Price. Small, Maynard & Co.
6. Earth and Sky Every Child Should Know, J. E. Rogers. Doubleday, Page & Co.
7. Farm Science, W. J. Spellman. World Book Company.
8. Elementary Agriculture, J. S. Grim. Allyn and Bacon.

PROJECT XXVIII

HOW PLANTS AND ANIMALS MAKE USE OF THE FOOD MANUFACTURED BY PLANTS

Problem 1. Why must plants and animals have food? — Compare the growth of a bean or pea seedling, from which the seed leaves have been removed, with the growth of one from which they have not been removed. What is the result? Since the food for the growing seedling is stored up in the seed leaves, what is your conclusion?

Your observations are sufficient without any experiments to prove to you that animals also must have food. The question is: Why is food so necessary?

We know that animals and plants exert energy. Plants are able to push their roots through the soil and against the force of gravity Give examples of this. Likewise, animals have the power of movement, produce heat, and are able to do work. Knowing that animals and plants breathe in oxygen and breathe out carbon dioxide, and that food must be taken in, what is your conclusion as to what happens to some of the food in the body? One use of food, therefore, is to act as a fuel which when burned furnishes heat, and power to do work.

Another use of food is evident to you; you weigh more this year than you did last year; you say that you have grown; your bones have become longer and thicker; muscles are larger; heart is a little bigger, etc. Where did the additional material come from? What, then, will you conclude

is another reason why plants and animals, and we, ourselves, must take in food?

In the work of the body there is a certain amount of wearing away of its parts. This wear evidently must be made good by food being built up into the muscles, nerves, and other parts of the body. State, now, the three uses made of food by plants, animals, and the human body.

FIGURE 261.—LUMBERMEN AT WORK. Why do these men need a large amount of energy-producing food?

Our next question naturally will be: What foods are good for each of these purposes?

Problem 2. What foods are good for fuel, and what ones for growth and repair? — Consideration of the kinds of food that are eaten under certain conditions may help us to solve this problem. People living in the Arctic regions must have food which will produce a great deal of heat. You all know that fat forms the greater part of their diet. What will be your conclusion, therefore, as to the value of fat in the food? Consider your own diet in regard to the use of fat. Do you eat a greater quantity in winter or in summer?

The hard work of lumbermen in the northern woods is done chiefly in winter (Figure 261). They need food which will

give them heat, and the power to do hard work. They eat much fat meat, as you would expect, but they also eat a great amount of molasses, large quantities of potatoes, and other starchy foods. This is an indication of the value of foods which contain starch and sugar.

These observations concerning the use of fats, starch, and sugar are in harmony with experiments which have been made as to the value of different food substances. Starches and sugar, which together are called *carbohydrates*, and fats because they are common to so many foods, are called *food principles* or *nutrients*.

We have already decided that foods, in addition to furnishing energy, are also necessary for growth and repair. For this purpose it has been found that there must be present a food principle or nutrient called *protein*, and certain mineral substances. These contain elements which are not present in fats and carbohydrates but which are necessary for the building of different parts of the body.

For example, living matter contains nitrogen; and as protein is the only nutrient which contains nitrogen, it is necessary for growth and repair of living matter. Foods containing a large percentage of protein are lean meat, fish, eggs, milk, cheese, beans, and peas, and to a lesser extent cereals (oats, wheat, barley, and rye).

Mineral matters are not only necessary for the making of new living matter and for the formation of the bones of the body, but their presence is necessary for the action of nerves and muscles, and for the passing of liquids through the walls of the small blood vessels and through other membranes. Iron has a special duty in forming the coloring matter of the red blood corpuscles. Mineral materials are very widely distributed among foods. Most natural foods contain

considerable mineral matter, so that usually the ordinary diet contains a sufficient amount. Milk, eggs, lean meat, leafy vegetables, fruits, and flour made from the whole grain

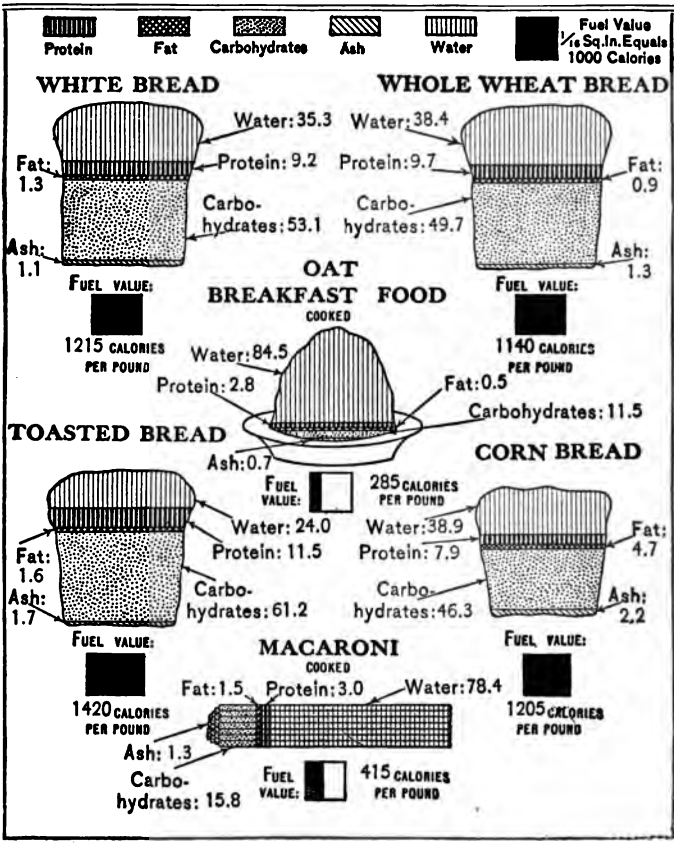


FIGURE 262.—COMPOSITION OF BREAD AND CEREAL FOODS.

are especially rich in mineral matter and very nutritious.

Recent experiments have shown that unless certain chemical substances (vitamines) which are found especially

in green vegetables and milk are present, normal growth does not occur. Therefore, it is very important to include these in the diet.

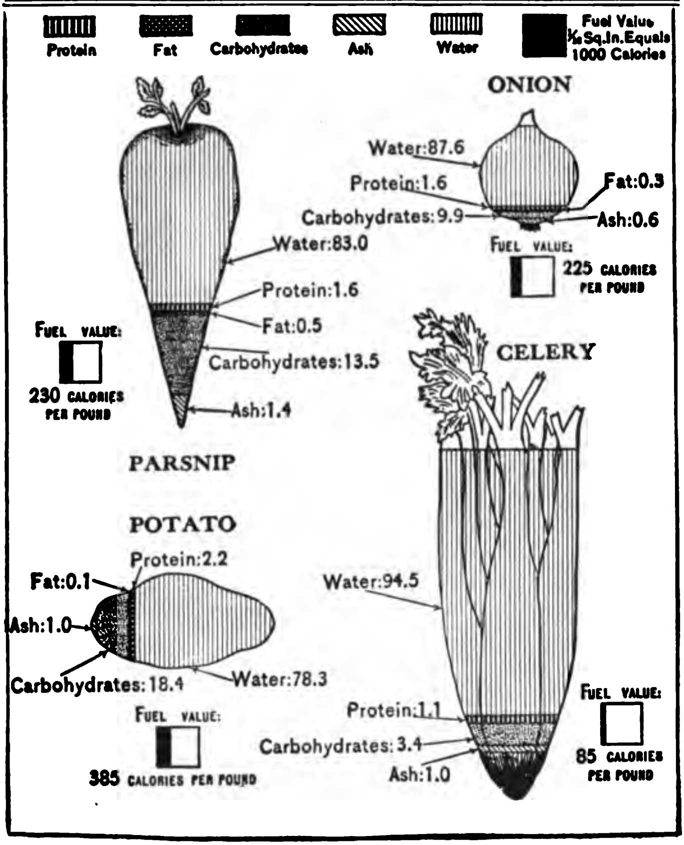


FIGURE 263.—COMPOSITION OF SOME COMMON VEGETABLES.

Name ten foods that are good for supplying energy.
Name five foods that are good for growth and repair.

Problem 3. How the fuel value of foods is measured.

Foods burned outside of the body furnish the same amount of energy as if they were burned within the body. The fuel

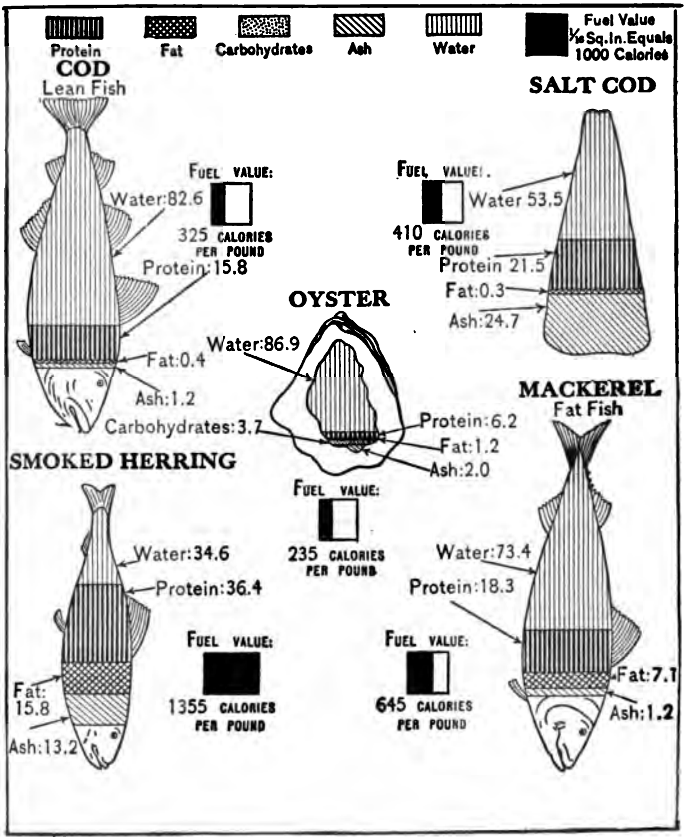


Figure 264. — Composition of Fish and Oysters.

value of carbohydrate, fat, and protein is therefore obtained by burning known amounts of these nutrients in an instrument called a *calorimeter*, so constructed that all the heat produced is used to heat a measured amount of water. The

amount of heat necessary to warm a kilogram of water one degree Centigrade, is taken as the unit. This unit is

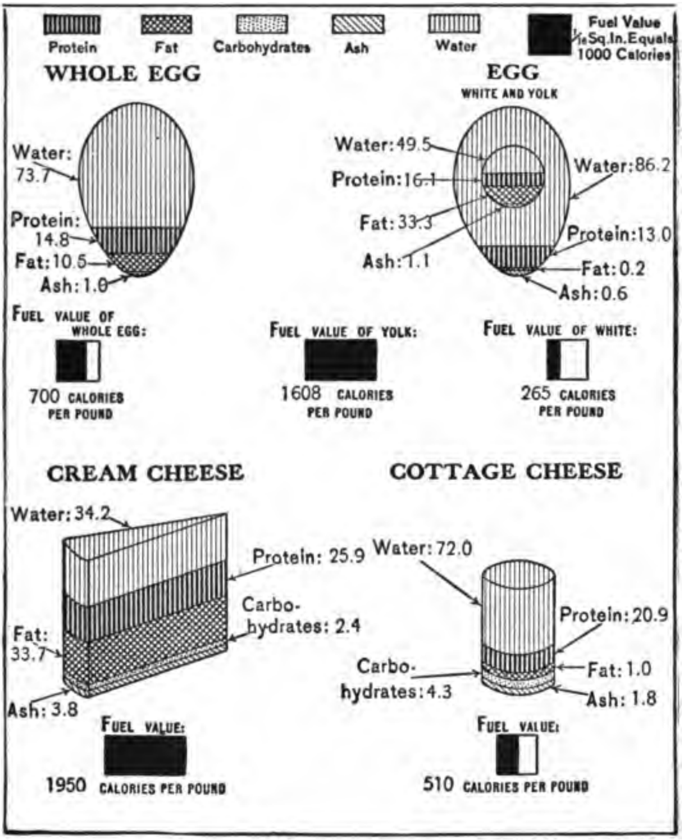


FIGURE 265. — COMPOSITION OF EGGS AND CHEESE.

called a *great calorie.* A pound of pure starch, sugar, or protein will yield when burned about 1850 calories, and a pound of pure fat about 4220 calories.

It can be seen that if the amount of these nutrients in a

food are known, it is very easy to calculate the fuel value of the food. The following table, compiled by Dr. Irving

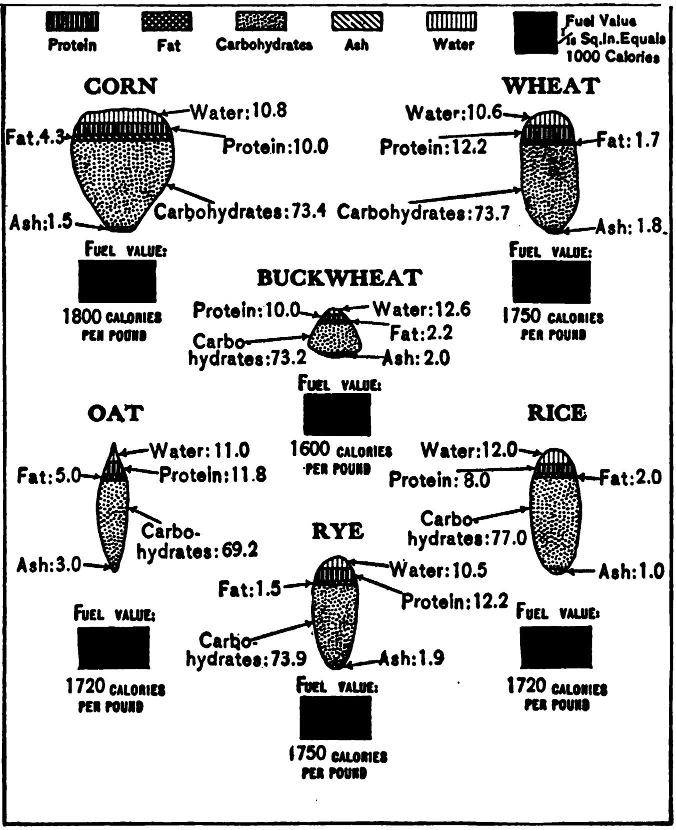


FIGURE 266.—COMPOSITION OF VARIOUS GRAINS USED FOR FOOD.

Fisher of Yale, gives the amount of each of a number of common foods which will furnish 100 calories.

Problem 4. What is the proper amount of food? — We know from experience that the amount of food needed is

not the same for all persons, and not even the same for one person under all circumstances. Fortunately, if we are in good health the appetite is a fair guide, although if it is disregarded and abused it soon becomes unreliable. Eating between meals, eating highly flavored food, etc., destroys the keenness of the appetite and either undereating or overeating may result. It is necessary, therefore, to know what the body needs under certain conditions so that the appetite may not lead us astray.

Your own experiences will indicate to you some of the conditions that determine the amount of food needed by the body as indicated by the appetite. Do you eat more food when you have been spending the day reading or when you have been playing outdoors or doing some active work? Why do you think this should be true? Do you eat more food in summer or in winter? Explain the reason for this. In both of these cases should the increase be in energy-producing food or in food used for growth and repair? Suggest how you think the diet should be modified at such times?

Experiments have shown that there is no need for any increase of protein, or building material, in the diet at times when the body is exerting more energy than usual, but that the increase in the amount of food should be by additions of fats or carbohydrates.

Growing children, of course, should have a slightly higher percentage of protein in their food than adults. Explain. This is well illustrated by the fact that milk, which should always be an important part of the food of children and which in the earliest years constitutes either all or a very large part of their diet, has a higher percentage of protein than is demanded by people who are no longer growing.

TABLE OF 100-CALORIE PORTIONS[1]

Edible Portions	Approximate Measure of 100-Calorie Portion	Weight in Ounces of 100-Calorie Portion	Calories Derived from Protein
Almonds	15 average	0.5	12.6
Apples	2 medium	5.6	2.5
Apricots, fresh	2 large	6.1	7.7
Asparagus, cooked	2 servings	7.5	17.9
Bacon, smoked (uncooked)	1 thin slice, small	0.6	6.7
Bananas	1 large	3.6	5.3
Beans, baked, canned	1 small serving (½ cupful)	2.8	21.5
string, canned	5 servings	17.2	21.5
lima, canned	1 large saucedish	4.6	20.8
Beef, corned		1.2	21.2
dried, salted and smoked	4 large slices	2.0	67.2
porterhouse steak	1 small steak	1.3	32.4
ribs, lean	1 average serving	1.9	42.3
ribs, fat		0.9	15.6
round, free from visible fat	1 generous serving	3.1	80.7
rump, lean		1.7	41.0
rump, fat		0.9	17.5
sirloin steak	1 average serving	1.4	31.0
Beets, cooked	3 servings	8.9	23.2
Brazil nuts	3 average size	0.5	10.2
Bread, graham	1 thick slice	1.3	13.5
toasted	2 medium slices (baker's)	1.2	15.2
white homemade	1 medium slice	1.3	13.8
average	1 thick slice	1.3	14.0
whole wheat	1 thick slice	1.4	15.9
Buckwheat flour	¼ cupful	1.0	7.4

[1] The Approximate Measure of 100-Calorie portions is based in part upon "Table of 100 Food Units," compiled by Dr. Irving Fisher. The Weight in Ounces of 100-Calorie Portions and Calories derived from Protein are based upon data found on page 319 of "Chemistry of Food and Nutrition," by Henry C. Sherman.

Edible Portions	Approximate Measure of 100-Calorie Portion	Weight in Ounces of 100-Calorie Portion	Calories Derived from Protein
Butter	1 tablespoon (ordinary pat)	0.5	0.5
Buttermilk	1¼ cupfuls (1⅓ glasses)	9.9	33.6
Cabbage	2 servings	11.2	20.3
Calf's-foot jelly		4.1	19.8
Carrots, fresh	2 medium	7.8	9.7
Cauliflower[1]		11.6	23.6
Celery		19.1	23.8
Celery soup, canned	2 servings	6.6	15.7
Cheese, American pale[1]	1⅓ cubic inches	0.8	26.5
American red[1]	1⅓ cubic inches	0.8	26.0
Cheddar[1]	1⅓ cubic inches	0.8	24.4
Cottage	4 cubic inches (¼ cupful)	3.2	76.1
Neufchatel	1⅓ cubic inches (¼ cupful) (⅓ small package)	1.1	23.2
Roquefort[1]		1.0	25.3
Swiss	1⅓ cubic inches	0.8	25.4
Chicken, broilers	1 large serving	3.3	79.1
Chocolate	"generous half" square	0.6	8.3
Cocoa	2⅓ tablespoonfuls	0.7	17.3
Cod, salt		3.4	97.5
Corn, green[1]	1 side dish	3.6	11.4
Corn meal	2 tablespoonfuls	1.0	10.3
Crackers, graham	3 crackers	0.9	9.6
soda	3 crackers	0.9	9.4
water	3 crackers	0.9	10.3
Cranberries[1]	1 cupful (cooked)	7.5	3.4
Cream	¼ cupful	1.8	5.0
Cucumbers	2 large	20.3	18.4
Dates, dried	4 medium	1.0	2.4
Doughnuts	½ doughnut	0.8	6.2
Eggs, uncooked	1⅓ medium or 2 small	2.4	36.4
Farina		1.0	12.3
Figs, dried	1 large	1.1	5.5
Flour, rye	¼ cupful	1.0	7.9
wheat, entire	¼ cupful	1.0	15.5
wheat, graham	¼ cupful	1.0	14.9
wheat, average high and medium	¼ cupful	1.0	12.8

[1] As purchased.

Edible Portions	Approximate Measure of 100-Calorie Portion	Weight in Ounces of 100-Calorie Portion	Calories Derived from Protein
Gelatin	4 tablespoonfuls	1.0	98.7
Grapes	1 large bunch	3.7	5.4
Haddock		4.9	96.3
Halibut steaks	1 average serving	2.9	61.8
Ham, fresh, lean		1.5	44.0
fresh, medium	1 average serving	1.1	19.0
smoked, lean		1.3	30.1
Herring, whole		2.5	54.6
Hominy, uncooked	1/4 cupful	1.0	9.3
Lamb, chops, broiled	1 small chop	1.0	24.3
leg, roast	1 average serving	1.8	41.0
Lard, refined	1 tablespoonful (scant)	0.4	(—)
Lemons	3 medium	8.0	9.0
Lettuce	50 large leaves	20.4	25.2
Liver, veal, uncooked	2 small servings	2.9	61.6
Macaroni, uncooked	1/4 cupful (4 sticks)	1.0	15.0
Macaroons	2	0.8	6.2
Mackerel, uncooked	1 large serving	2.5	53.9
salt		1.2	29.5
Marmalade, orange	1 tablespoonful	1.0	0.7
Milk, condensed, sweetened	1 1/16 cupfuls	1.1	10.9
skimmed	1 1/4 cupfuls (scant)	9.6	37.1
whole	5/8 cupful (generous half glass)	5.1	19.1
Molasses, cane	1/3 cupful	1.2	3.4
Muskmelons	1/2 average serving	8.9	6.0
Mutton, leg	1 average serving	1.8	41.2
Oatmeal, uncooked	1/3 cupful	0.9	16.1
Olives, green	7 to 10	1.2	1.5
Onions, fresh	2 medium	7.3	13.2
Oranges	1 very large	6.9	6.2
Oysters, canned	5 oysters	4.9	48.6
Parsnips	1 large	5.4	9.9
Pea soup, canned		6.9	28.2
Peaches, canned	1 large serving	7.5	6.0
fresh	4 medium	8.5	6.8
Peanuts	10 to 12 (double kernels)	0.6	18.6
Peas, canned	2 servings	6.3	25.9
Peas, dried, uncooked	2 tablespoonfuls	1.0	27.6

[1] As purchased.

Edible Portions	Approximate Measure of 100-Calorie Portion	Weight in Ounces of 100-Calorie Portion	Calories Derived from Protein
Peas, green	1 generous serving	3.5	28.0
Pies, apple	⅓ piece	1.3	4.6
custard	⅓ piece	2.0	9.4
lemon	⅓ piece	1.4	5.6
mince	¼ piece	1.2	8.1
squash	⅓ piece	2.0	9.9
Pineapples, fresh	5 slices	8.2	3.7
canned	1 small serving	2.3	1.0
Pork, chops, medium	1 very small serving	1.1	19.9
fat, salt[1]		0.5	1.0
Potatoes, white, uncooked	1 medium	4.2	10.6
sweet, uncooked	½ medium	2.9	5.8
Prunes, dried	3 large	1.2	2.8
Raisins	⅓ cupful (packed solid)	1.0	3.0
Rhubarb, uncooked	3½ cupfuls (scant)	15.3	10.4
Rice, uncooked	2 tablespoonfuls	1.0	9.3
Salmon, whole	1 small serving	1.7	43.1
Shad, whole	1 average serving	2.2	45.9
Shredded wheat	1 biscuit	1.0	11.3
Spinach, fresh[1]	3 ordinary servings (after cooking)	14.7	35.0
Succotash, canned	1 average serving	3.6	14.7
Sugar	3 lumps, 5 teaspoonfuls granulated 6½ teaspoonfuls powdered sugar	0.9	(—)
Tomatoes, fresh	4 average servings	15.5	15.8
canned	1¾ cupfuls	15.6	21.3
Turkey	1 serving	1.2	28.7
Turnips	2 large servings (2 turnips)	9.0	13.3
Veal, cutlet		2.3	53.6
fore quarter		2.3	52.8
hind quarter		2.3	53.0
Vegetable soup, canned		25.9	85.3
Walnuts, California	4 whole nuts	0.5	10.3
Wheat, cracked		1.0	12.4
Whitefish		2.4	61.4
Zwieback	1 thick slice	0.8	9.4

[1] As purchased.

Another condition which will affect the amount of food needed is the size of the body. Other conditions being the same, a small person needs somewhat less food than a larger person. It has been calculated that the number of calories which should be supplied by the food when light work is being done may be determined by multiplying the weight of the body by 16.1. Thus a person weighing 160 pounds will need sufficient food to furnish 2576 calories. Of course, if more active muscular work is being performed, food producing a greater number of calories is needed. A man doing moderately active work needs about 3000 calories; a farmer during the busy season, as much as 4000 calories; and lumbermen, from 5000 to 9000 calories.

The proper amount of protein in the diet has been a much discussed question. This is of great importance, since an excess of protein in the diet is harmful to the body. The tendency of the American people is to eat rather more protein than is absolutely necessary, and therefore in most cases the diet would be improved by cutting down the foods rich in protein; for example, meats. About two and one half ounces or from 70 to 80 grams of protein a day seem to be sufficient, according to experiments. It will be found, however, that our actual diet is likely to have nearly three and one half or four ounces or about 100 grams of protein.

Problem 5. What considerations should govern the planning of our diet?—It is evident that our diet must have the proper fuel value, and contain the proper amount of protein. Since there is usually too much protein in an unrestricted diet, large amounts of lean meats and other foods containing a high percentage of protein should be avoided. It would be well to calculate by the use of the 100-calorie portion tables given the calorie value of your food for a day. If more

than 15 per cent of the calories are from protein, then your diet is too rich in that. An excess of fat or carbohydrate in the diet is apt to cause an increase of weight due to the storing up of excess fuel in the form of fat.

A diet which contains the proper amount of protein, carbohydrate, and fat may, however, be a very unsatisfactory one. There must be included in it foods which will supply the minerals needed by the body, and those minute substances sometimes called *vitamines*, without which normal growth and repair does not occur. Vegetables, whole grain bread and cereals, fruits, and milk are especially valuable for their minerals. Milk and leafy vegetables such as lettuce and spinach are indispensable in the diet. Fruits and coarse elements in the food such as the bran or outer coat of wheat exert a beneficial effect upon the digestive organs.

A good diet, therefore, will be one which supplies the proper amount of the three nutrients, and includes milk, leafy vegetables, some fruit and coarse food such as whole wheat bread, and is so varied as not to become monotonous. It is presumed, also, that those parts of the food which are cooked have been made both more digestible and more appetizing, and that there has been no waste of their elements.

Problem 6. Why must foods be digested? — Consider the condition in the corn seedling. Where is the food stored? Where is growth going on, and where is energy being exerted? The food then must be able to travel from the seed to the growing point. But the young stem and root, just as we saw in the older root and in the leaves, are made up of little box-like structures (Figure 267) (cells) so that the food in reaching the point where it is needed must pass through hundreds of the thin walls of these cells. The question now is, is the stored-up food in condition to pass through these

membranous walls? The following experiment will enable you to answer this question.

Experiment. — Break off the bottom of a test tube so that it forms a tube open at both ends. Over one end of it tie a piece of parchment paper or a piece of the dried bladder of a pig or other animal. Place the tube with the parchment end down in a vessel of water in which has been stirred some starch. After about an hour test the water which has come into the tube through the parchment for the presence of starch. This test is made by adding to the water an iodine solution which turns it blue if starch is present. What is the result? What is your conclusion?

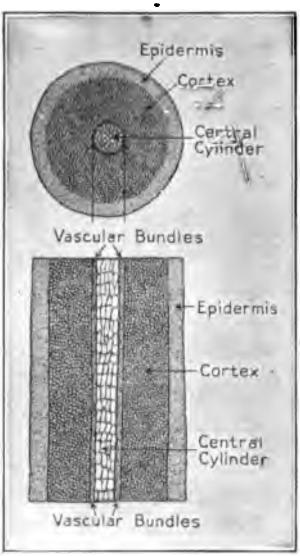


FIGURE 267. — CROSS AND LONGITUDINAL SECTIONS OF A YOUNG ROOT.

Note that the entire root is made up of small divisions (cells), every one of which is surrounded by a thin membrane.

The parchment or membrane represents the cell walls through which the food must pass. Evidently the starch must be changed into something else or it can be of no value to the plant. Since we know that it disappears from the seed and that energy is exerted at the growing point, then we know that it is changed into something which will pass through the walls.

The protein and the fat stored in the seed are also unable to pass through membranes and they too must be changed. The process by which all of these foods are changed is called *digestion.* Our own foods must be changed in the same way; starch, protein, and fats are unable to

get into our blood until they are changed into something which is able to pass through membranes.

Problem 7. How can we prove that nutrients are digested? — We have already seen that starch cannot pass through a membrane and that it must be changed into something that will. Since sugar is very similar to starch in its chemical composition, we may suspect that starch may be changed into sugar during digestion. But is sugar able to pass through a membrane?

This may be determined by trying the same experiment as before, except that a solution of grape sugar should be substituted for the mixture of starch and water. The water passing through the membrane may be tested for grape sugar by heating some of it to which has been added a few drops of Fehling's solution. The presence of grape sugar is indicated by a reddish orange or brick red color. What is the result in this case? What is your conclusion?

Grind up an unsprouted corn grain, mix it with a little water, and test for grape sugar. Result? Do the same with sprouting corn grain. Result? Conclusion?

Chew up a piece of cracker which has been shown by a test to contain no grape sugar. After it has been thoroughly chewed and mixed with saliva, test again for grape sugar. Result? Conclusion?

There is evidently something in the sprouting corn grain and in the saliva which has the power to change starch into sugar. A substance of this kind, which by its presence is able to cause other substances to change chemically, remaining unchanged itself, is called an *enzyme*. In the corn grain the enzyme becomes active only when the proper conditions of temperature and moisture are present. There are also enzymes that act upon proteins, and others that act upon fats.

Problem 8. Where is food of the human body digested? — We know that food taken into the mouth passes down through the gullet into the stomach, where it remains for several hours, and then passes into the small intestine, and on into the large intestine. This entire tube extending from the mouth to the end of the rectum, the last division of the large intestine, is called the *alimentary canal.* The food is forced along through this tube by means of muscles in its walls.

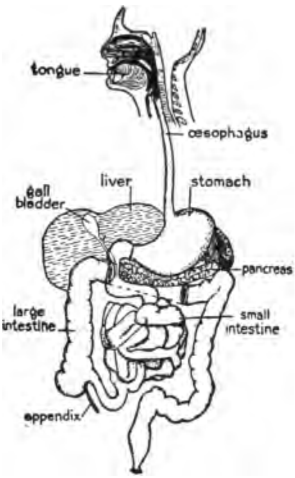


FIGURE 268. — FOOD CANAL (ALIMENTARY CANAL) OF MAN.

After the food has been broken up by the teeth and mixed with saliva which acts to some extent upon the starch, it is worked upon by enzymes of the gastric juice of the stomach which act chiefly upon the protein food, and by a number of enzymes from the pancreatic juice and intestinal juice which act upon all of the different nutrients. The bile, a juice manufactured by the liver, is of special use in digesting fat. As the food is digested, it is absorbed through the walls of the alimentary canal. Most of the absorption occurs in the small intestine.

The material which reaches the large intestine is principally food which could not be digested and hence could not be absorbed. If this refuse material remains too long in the large intestine, which is the condition in constipation, bacteria act upon it and produce soluble poisons which are absorbed

into the blood through the walls of the large intestine and give rise to headaches, an inability to do our best mental and physical work, and make the body, less able to resist disease.

By the circulatory system of the blood (Figure 269) the digested food is carried to various parts of the body, where it is used for growth and repair and as a fuel for the production of energy, or the excess of fuel food is stored up in the form of fat.

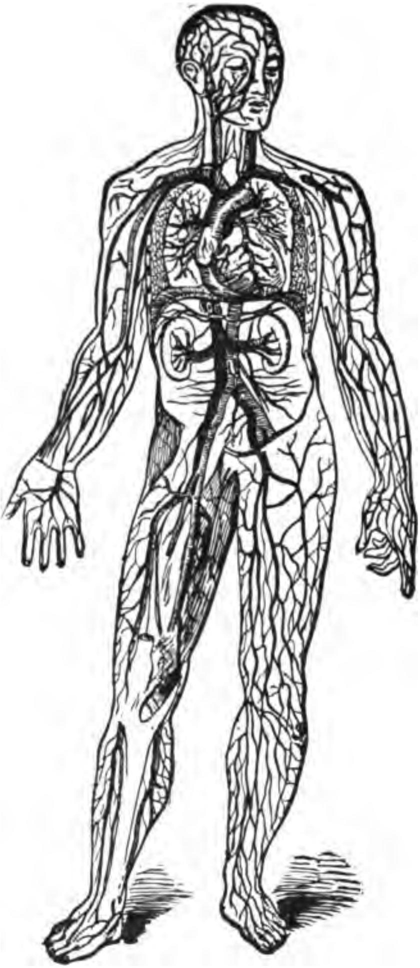


FIGURE 269.—ORGANS OF CIRCULATION OF MAN.

The wastes which are produced in the different parts of the body as a result of oxidation and the activity of the living matter, are, in time, carried away by the circulatory system to the kidneys, lungs, and skin, by which they are taken out of the blood.

Suggested Individual Projects

1. By weighing the food used each day for a week and calculating from tables showing percentage of nutrients in different foods, determine the amount of each nutrient eaten by you during the week. How does the result compare with the standard of Atwater or Chittenden?

2. Plan a bill of fare for your family for a week. Estimate the amount of nutrients and the cost. Suggest how the diet of your family might be improved without any great increase in cost.

3. Perform experiments to show that the gastric juice will digest protein.

4. Dissect the heart of a sheep. Explain its action in causing a circulation of the blood.

Reports

1. The value of milk as a food.
2. The use of fruit and fresh vegetables as foods.
3. Causes and prevention of indigestion.
4. Causes and prevention of constipation.

References for Project XXVIII

1. Feeding the Family, Mary S. Rose. Macmillan Company.

2. The Story of Sugar, G. T. Surface. D. Appleton & Co.

3. Food and Household Management, Kinne and Cooley. Macmillan Company.

4. How to Live, Fisher and Fisk. Funk & Wagnalls.

5. All About Milk. Metropolitan Life Insurance Company. (Free.)

6. The Body at Work, Jewett. Ginn & Co.

7. Town and City, Jewett. Ginn & Co.

8. The Story of Bread. International Harvester Company, Chicago, Illinois.

9. Economy in the Buying and Preparation of Meats, E. L. Wright. Wilson & Co.

10. American Inventions and Inventors, Mowry. Silver, Burdett & Co. (Foods cultivated and uncultivated.)

PROJECT XXIX

HOW PLANTS PRODUCE SEED

Problem 1. Why plants produce seeds?—Make a list of the plants you know which produce seeds. In making this list, include grains and nuts as seeds. What is your conclusion concerning the number of plants which produce seeds? If a seed is placed in the soil with the proper conditions of moisture and temperature, what finally develops from it? If a farmer wishes new wheat or grass or bean plants, what does he do?

If you have a garden, after the soil has been prepared you plant seeds in it which either you or the seedsman have obtained from plants grown the previous year. Weeds may die as winter comes, but before this happens they have produced large numbers of seeds which fall to the ground and remain there until the following spring. Considering these and other observations which you have made, what is your answer to the question, why do plants produce seeds? Why do you suppose plants produce so many seeds?

Problem 2. What are the parts of a seed?—Soak a number of rather large seeds as peas, beans, or corn. Examine a bean seed. It will be noticed that there is a scar on one edge. To understand the cause of this scar, open a bean pod and note how the seeds are attached. While the seed is growing, what do you suppose passes through the little stalk by which the seed is attached to the side of the pod? The

point of attachment of this little stalk to the side of the pod is called the *placenta*. What materials pass through the placenta?

Remove the seed coat and find two large structures that make up almost the whole bulk of the seed (Figure 270). These are called *seed leaves*, and it will be noted that they are attached to a little stalk, the pointed end of which will later develop into the root of the growing bean plant. At the other end of the little stalk, and just beyond where the big seed leaves are attached, you will see two little plume-like structures which at first look like the parts of a fish's tail, but on closer examination prove to be small leaves. These leaves, with the very small stalk to which they are attached, will develop into the stem and leaves of the plant.

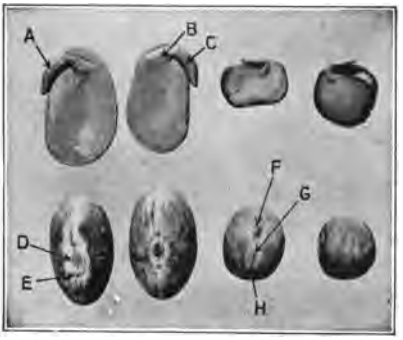


FIGURE 270.—SEEDS OF BEAN AND PEA.

A and *C*, little stem, lower end of which will develop into the first roots. *B*, plumule, a bud which will develop into the stem and leaves of plant. *A*, *B* and the two large seed leaves constitute the embryo. *D*, scar, the place of attachment of the little stalk within the bean pod. *E*, micropyle, a small opening.

Altogether the bean seed is made up of a little plant called an *embryo*, of which two leaves are filled to such an extent with food material that they have become so thickened that they no longer look like leaves. These constitute the seed leaves. Compare the embryo making up the seed of the bean with a bean seedling. Pick out the corresponding parts.

Examine a soaked pea seed and endeavor to find the same parts that you found in the bean seed. In the same way compare the embryo of the pea seed with a pea seedling and note the corresponding parts.

A corn seed may be best studied if it is examined together with one which has begun to sprout (Figure 271). The part which corresponds to the root end of the little stem can easily be seen, as in whatever position the corn grain is kept this root end begins to grow downward. The other end, which begins to push upward to form the main part of the plant, is pointed and made up of tightly twisted leaves in much the same way that you can furl up a piece of paper leaving a sharp point at one end.

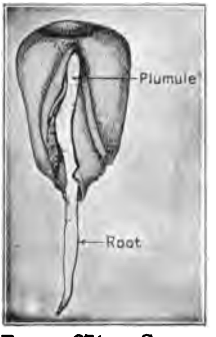


FIGURE 271.—SPROUTING CORN GRAIN.

The seed leaf (there is only one) is not at all leaf-like in appearance but is embedded in stored food material which in the corn seed is outside of the embryo. The relation of the seed leaf to the stored food material can best be seen by cutting lengthwise and cross sections of soaked corn grains, and dipping the cut surfaces in an iodine solution. The stored food material, since it contains a very large amount of starch, becomes colored a very dark blue; while the parts of the embryo are colored very slightly.

It will thus be seen that the corn seed, although apparently so unlike the bean or pea seeds, also contains an embryo, or undeveloped plant, which consists of a seed leaf attached to a stalk, one end of which will develop into the roots, and the other end into the stem and leaves of the plant.

Examination of other seeds will show the same thing, so that we may conclude that the seed of a plant always contains an embryo or baby plant with considerable stored-up food which may either be in the seed leaves or outside of the embryo.

Problem 3. Where seeds are produced. — It is a common observation that seeds are produced in some way by

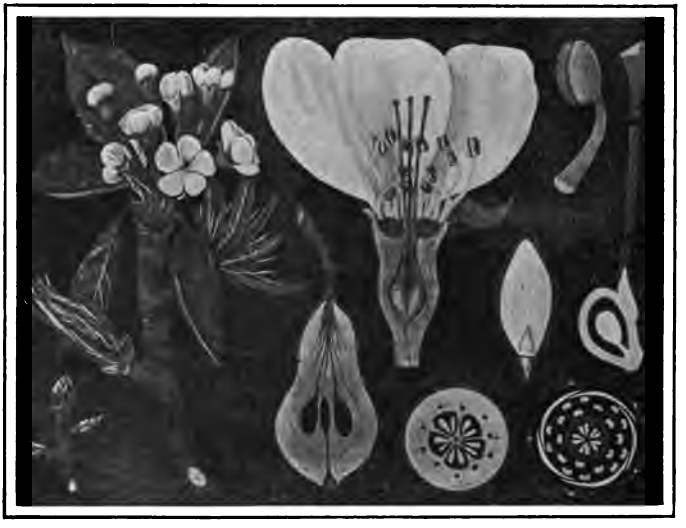


FIGURE 272.—PEAR, FROM BUD TO FRUIT AND SEED.

the flowers of a plant. It will be well for us, therefore, to examine a flower. An examination of a typical flower, such as a pear blossom or bean or pea blossom, will lead us to find the following parts (Figure 272):

The outermost parts are green leaf-like structures called *sepals*. Together they make a cup-shaped formation around the base of the flower called the *calyx*. Just inside of these are the colored parts of the flower called the *petals*. The

petals together constitute the *corolla.* Next there are a number of little stalks with knobs on their tops. These are the *stamens*, the stalks being called *filaments*, and the knobs at the top, *anthers*. The anthers are little box-like structures containing a powdery substance called *pollen.*

The center of the flower is occupied by the *pistil*, of which there are usually three divisions: an enlarged part at the base called the *ovary*, one or more little stalks running up from this called *styles*, and at the top of the styles enlargements usually slightly rough and moist called *stigmas*. If the ovary is cut through, there will be found in it small seed-like structures which are called *ovules*. Very evidently, these are the parts of the flower which will develop into seeds.

Problem 4. Do ovules always develop into seeds? — Apparently, ovules do not necessarily develop into seeds. It will be found by an examination of a number of pea or bean pods that occasionally an ovule has not developed into a seed. An account of some experiments which have been performed many times will help us to understand why ovules do not always develop into seeds. Stamens were carefully removed from a flower before any pollen had escaped from the anthers. The flower was then covered with a fine netting or a paper bag. None of the ovules developed into seeds.

This would indicate that the pollen is necessary for the production of the seeds. This conclusion may be confirmed as follows: A flower was treated as the one described above; but in this case some pollen from another flower of the same kind was placed upon the stigmas of the flower from which the stamens had been removed. The ovules all developed into seeds. What conclusion will you draw from this result?

Problem 5. How the pollen grain influences the development of the ovule into the seed. — It has been found that each pollen grain resting upon the surface of the stigma grows out into a tube which pushes its way down through the style until it reaches the ovary (Figure 273). The pollen tube now grows through a small opening (*micropyle*) on the side of the ovule (Figure 274). Some of the living material (*sperm cell*) of the pollen grain, containing a denser portion, the *nucleus*, passes down through the tube.

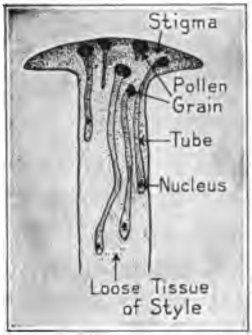


FIGURE 273. — GROWTH OF POLLEN TUBES DOWN THROUGH THE STYLE.

After the tube has penetrated into the ovule through the micropyle, the end of the tube disappears and the nucleus of the pollen (sperm cell nucleus) combines with the nucleus of a little bit of living matter in the ovule called the *egg cell.* The egg cell, which is now composed of living material from the pollen grain in addition to its own original living material, grows and divides into two, then four, eight, and finally thousands of little masses of living matter (*cells*) which arrange themselves to form the parts of the embryo or baby plant.

The egg cell, which is composed of living material from these two sources, is called a *fertilized* egg cell; and the union of the sperm cell nucleus with the egg cell nucleus is called the process of *fertilization.* Unless this process of fertilization occurs, the egg cell will not grow and divide, but will finally wither and die.

In all living things except the very lowest animals and plants, this general process of the union of two masses of

living matter precedes the development of an egg into a new plant or animal.

Problem 6. Does it make any difference whether the pollen comes from the same flower or a different one? — It is clear that if seeds are produced by a plant the pollen must in some way pass from the anther to the stigma. This would seem very easy, as the flowers of most plants have both stamens and pistils. Experiments, however, by the great English scientist, Charles Darwin, have shown that in many plants *cross-pollination* (transfer of pollen from an anther of one flower to the stigma of another flower of the same kind) gave much more satisfactory results than if the pollen that fell upon the stigma came from the anther of the same flower (*self-pollination*). He found in some cases of self-pollination that a smaller number of seeds were produced; that the seeds were frequently smaller and that poorer plants developed from the seeds. Naturally the question arises as to how self-pollination is prevented, and how cross-pollination is encouraged.

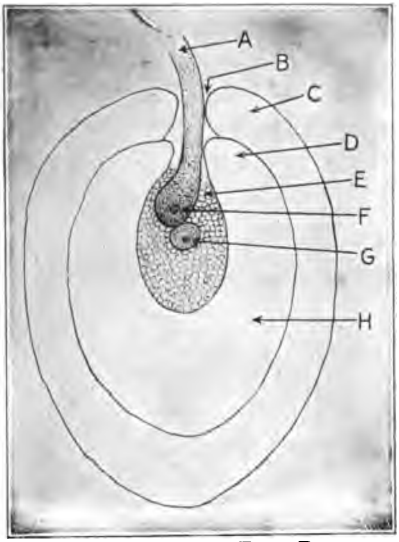


FIGURE 274. — POLLEN TUBE ENTERING OVULE.

A, pollen tube; *B*, micropyle; *C*, outer coat of ovule; *D*, inner coat of ovule; *E*, embryo sac; *F*, sperm cell nucleus; *G*, egg cell nucleus.

Problem 7. How self-pollination is prevented. — Some plants, like the willow and the cottonwood or poplar, have flowers containing only stamens on one plant and flowers having only pistils on another plant. In these cases self-pollination is impossible. Other plants, among which are corn (Figures 275 and 276) and many of our common trees as ash, chestnut (Figure 277), oak (Figure 278), maple, hickory, pines, etc., have stamens and pistils in different flowers but on the same plant.

FIGURE 275. — PISTILLATE FLOWERS OF CORN.

Each silk (style and stigma) is attached at its base to the young corn grain (ovary).

In corn, for example, the tassel (Figure 276) at the top of the corn plant is a collection of staminate flowers; while the silks (Figure 275) of the ear of corn, down along the stalk, are stigmas and styles, and the corn grains are ovaries of the pistillate flowers. Even in this kind of plants better results occur when the pollen is carried from the anthers of another plant. A solitary cornstalk usually has on it very poorly developed ears of corn.

In many plants the stamens ripen and the pollen escapes from the anthers before the stigmas in the same flower are ready to receive it. In some plants the reverse is true, the stigma being ready to receive pollen before the pollen in that plant is mature.

Experiments have shown that in some flowers if the pollen from the same flower and pollen from a different flower of the same kind are placed side by side upon the stigma, the pollen tube of the pollen of the other flower will grow more rapidly than the tube of the pollen of the same flower.

Problem 8. How pollen is carried from one flower to another. — If a branch of a pine or oak tree or a piece of ragweed or a corn tassel is shaken slightly at the time the pollen is ripe, the pollen, in the form of a light, dry dust, will fall out in great quantities. How do you suppose pollen of these flowers may be carried from one flower to another? Explain the reason for the enormous quantity of pollen produced. The stigmas of flowers pollinated in this way are frequently very much enlarged and branched so as to expose a large surface. What is the advantage of this? These flowers that are pollinated by the wind do not correspond in their appearance to our idea of flowers. They are usually greenish and inconspicuous with no odor or bright colors.

FIGURE 276 — CORN TASSEL MADE UP OF STAMINATE FLOWERS.

Many flowers have pollen which is not so dry and light as that of the flowers we have been considering. They evidently cannot have pollen carried to any extent by the wind.

FIGURE 277. — STAMINATE FLOWERS OF CHESTNUT.

These are our familiar flowers (Figures 279 and 280), of various colors and frequently having more or less odor. You will recall that you have often seen insects, especially bees and butterflies, visiting them. The insects are seeking the sweet material, *nectar,* which is down in the interior of the flowers. By pulling out the little flowers from a head of red clover, and touching their bases with the tongue, you can taste the nectar. Examination of the head of a butterfly and

FIGURE 278. — FLOWERS OF OAK.

the legs and body of a bee will show you that they are covered with hairs. **Explain now how you believe these flowers are pollinated.**

The irregular shapes of flowers are in general associated with making more certain that the proper kinds of insects

FIGURE 279. — FLOWERS OF HORSECHESTNUT.

will visit them; and the stamens and pistils are so arranged that the insect is quite certain to rub against them to receive pollen from one flower, and then to rub the pollen off on the stigma of the next flower visited.

Some flowers have their pollen carried by water; and in some cases humming birds act as the carriers; but the great majority of flowers are pollinated either by wind or by insects. Insect-pollinated flowers have much less pollen than wind-pollinated flowers. Explain.

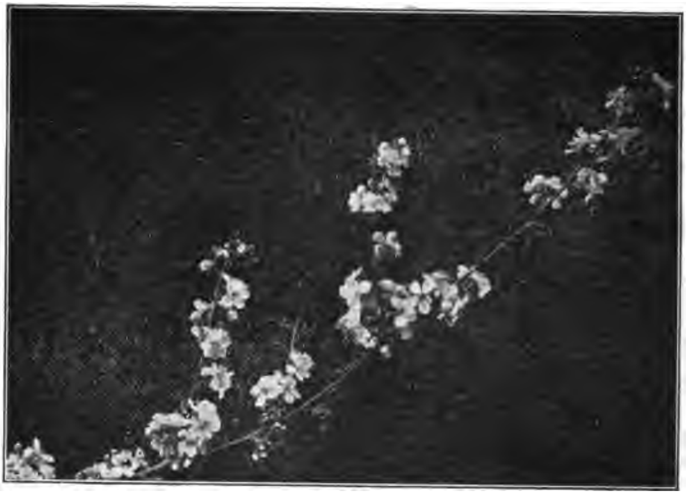


FIGURE 280. — CHERRY BLOSSOMS.
Suggest any advantage of the grouping into clusters of these small white flowers.

Nearly all of the flowers that bloom at night are white or yellow. What reason can you give for this? Flowers have various means of excluding small crawling insects like ants. Of what advantage is this to the plant?

SUGGESTED INDIVIDUAL PROJECTS

1. Make a collection of seeds and give a brief statement of the economic value of each seed.
2. Germinate ten different seeds. Make sketches of several stages of the development of each.

3. Examine ten different flowers. Make sketches of the essential organs of each.

4. Cross-pollinate a number of flowers of a plant.

5. Grow pollen tubes from the pollen of several kinds of flowers in sugar solutions of different densities.

6. Observe a bed of flowers for a considerable time to find out the kinds and numbers of insects that visit the flowers. Catch some of the insects and examine them to find whether they are carrying pollen and how well fitted they are for this purpose. Also determine whether the flowers are fitted in any special way to profit by the visits of the insects.

7. Make a collection of the flowers of a number of common trees.

8. Collect frogs' eggs and describe the changes which they undergo when kept in an aquarium.

Reports

1. Describe the methods of cross-pollination.

2. Describe special devices in several flowers to prevent self-pollination and to bring about cross-pollination.

References for Project XXIX

1. Farmers' Bulletin 154, The Home Fruit Garden; 218, The School Garden; 255, The Home Vegetable Garden; 408, School Exercises in Plant Production.

2. The Home Vegetable Garden, Adolph Kruhm. Orange Judd Company.

3. Outline Studies on School Garden, Home Garden, and Vegetable and Growing Projects, Kern. Division of Agricultural Education, University of California.

4. Wild Flowers Every Child Should Know, Stack. Doubleday, Page & Co.

PROJECT XXX

HOW BETTER PLANTS AND ANIMALS ARE PRODUCED

Problem 1. Have we evidence of improvement of plants and animals during past generations? — Of course we mean by improvement, making these plants and animals better fitted to meet our needs. The history of some of our domesticated animals and plants runs back to the point where our knowledge of the history of man begins, so that it is impossible to trace them directly from their wild ancestors. They may, however, be compared in some cases with wild plants and animals which apparently are similar to these unknown ancestors. Wheat, oats, rye, barley, etc., have evidently been derived from wild grasses, from which they now differ chiefly in the amount of food material stored in the grain or seed.

Chickens have changed much from the Asiatic bird which is thought to be most nearly like the one from which they have descended. Dogs have become quite unlike their wild ancestors, apparently wolves and coyotes or the close relatives of these. Turkeys, which have become domesticated in relatively recent times, have already begun to be changed in some respects from the wild turkeys which were found in the American woods by the early settlers.

The most striking effect of the influence of domestication in causing improvement in plants is shown by those plants which are native to America and whose whole histories are

known. The Indian corn, which explorers found the American Indians cultivating in a very crude way, would hardly be recognized as being related to the large-grained, full-eared corn whose crop in 1920 was worth over $4,000,000,000.

The potatoes found by these early explorers were about the size of marbles. During the few hundreds of years since they have been cultivated by civilized man, both quality and size have been greatly improved. In 1920 the average yield per acre was over 100 bushels; some areas yielding 300 to 400 bushels per acre.

Not only has there been an improvement under domestication of the plants and animals mentioned above, but the same is true to a greater or less extent of all plants and animals for which we have use. The question that arises in our minds is, how has this improvement been brought about, and how may we continue the process?

Problem 2. How plants and animals may be improved by selection. — From the very earliest times selection has been a factor in producing better animals and plants. Selection has depended upon two facts with which we are all familiar: first, that no two plants or animals are exactly alike; and second, that a plant or animal tends to be like its parents. In a classroom, for example, there are no two pupils exactly alike. This is also true if we consider all the people in the whole world. Likewise, you will find that no two bean or wheat plants or apple trees or horses are exactly alike (Figure 281). This we call *variation.*

On the other hand, each pupil in the class resembles his parents or grandparents in many respects. It may be in the shape of the nose or face, coloring, tone of voice, size, mental traits, etc. The same is true of every plant and animal. Chickens never come from duck eggs, or chestnuts

from cherry trees. Every plant or animal resembles its parents in hundreds of ways. This law of resemblance is called *heredity;* and we say that a person *inherits* a good disposition, black eyes, etc., from his antecedents. The farmer, who each year selects the best corn or wheat grains for seed,

FIGURE 281.—VARIATION.
Variation in the size and shape of timothy heads in the same kind of timothy.

will keep his crops up to the highest grade. He may select for any special characteristic; size of ear, rapid growth, large or small amount of starch, protein, or oil.

Problem 3. How more rapid improvement may be brought about. — Greater variation may be brought about by pollinating flowers by hand. By this means also, a variety of plant or fruit possessing certain desirable characteristics may be obtained rather quickly. For example,

edible oranges cannot be produced in a region where frosts are likely to occur. There is, however, a species of orange tree having a bitter, uneatable fruit which is very hardy and will grow much farther north than the sweet orange.

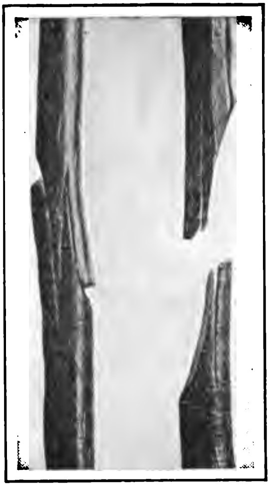


FIGURE 282. — TONGUE GRAFTING.

In all forms of plant grafting, it is essential that the actively growing layer (cambium) situated between the bark and the wood of the graft be held in contact with the cambium layer of the plant to which the graft is attached.

In 1896 and 1897, plant breeders of the United States Department of Agriculture attempted to produce an edible orange which would grow much farther north. This was done in the following way. Pollen from the flowers of the bitter orange was placed on the stigmas of flowers of the sweet orange and vice versa. This was done for thousands of flowers, and is called *hybridizing*.

There was great variation in the plants that developed from the seeds of these flowers. The young plants were grown where they would be exposed to considerable cold. Many of them could not withstand the low temperature and died. Others which showed good healthy growth in spite of the cold were *grafted*[1] upon orange trees. Out of the thousands

[1] That is, the end of the branch of an orange tree was cut off and in a slit cut in the end of it was placed a one-year-old seedling plant (the graft). The important thing about this is that the fruit borne on the grafted part is the same as though the twig had grown from its own roots.

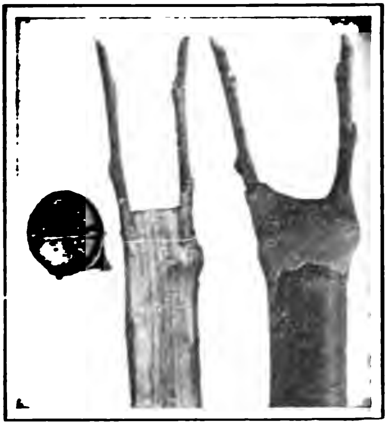


FIGURE 283. — CLEFT GRAFTING.

of grafts made, only three produced fruit that was of value. The flavor of these was good and they possessed the advantage of being able to live two to four hundred miles north of where the ordinary sweet orange was able to exist. These varieties were propagated in turn by further grafting.

In plants that can be propagated by cuttings, as roses, carnations, geraniums, etc.; by roots, rootstocks, or tubers,

FIGURE 284. — BUDDING, A FORM OF GRAFTING.
The four successive steps are shown left to right.

as potatoes, gladioli, etc.; or by grafting, as fruit trees, favorable variations obtained by hybridizing may be readily retained. In plants, however, that are propagated only by seed, as cotton, corn, wheat, most vegetables, etc., a process of rigorous selection must follow. After four to six generations the plants will "come true to seed" fairly well, but the process of selection must continue every year or the desirable characteristics will disappear.

Very striking results have been obtained by plant and animal breeders through the use of selection and hybridizing. Luther Burbank especially has developed some very interesting plants, such as the white blackberry and spineless cactus.

Suggested Individual Projects

1. From a corn or wheat crop, etc., make a selection of seed to bring about an improvement along some definite line in future crops.
2. Graft the twig of one kind of apple tree upon the limb of another.
3. Propagate a number of different kinds of plants by cuttings.

Reports

1. Improvement of the corn crop.
2. Improvement of the wheat crop.
3. Reports on various achievements of Luther Burbank.
4. The work of the U. S. Bureau of Agriculture in developing new species of animals and plants.
5. Give a brief account of the work of Charles Darwin.
6. Give a brief account of the work of Gregor Mendel.

References for Project xxx

1. New Creations in Plant Life: Life and Work of Luther Burbank, W. S. Harwood. Grosset & Dunlap, 1907.

2. Evolution of Our Native Fruits, L. H. Bailey. Macmillan Company.

3. The Story of a Grain of Wheat, W. C. Edgar. D. Appleton & Co.

4. Corn Plants, Their Uses and Ways of Life, F. L. Sargent. Houghton Mifflin Company.

5. Plant Production, Moore and Halligan. American Book Company.

PROJECT XXXI

INSECT ENEMIES OF PLANTS

Problem 1. How insects are injurious to plants. — Most of you know some of the ways in which insects are injurious to plants. You have seen rose bushes, currant bushes, or even whole trees stripped of their leaves by little worm-like animals (Figures 285 and 291). If you have had a garden or have been in the country in summer you have seen potato bugs, or more accurately, potato beetles (Figure 286).

FIGURE 285. — LIFE HISTORY OF GYPSY MOTH.

One of the insects most injurious to foliage of shade and forest trees. Common in the New England States.

You may have seen a little heap of sawdust at the foot of a plum, peach or cherry tree which led you to find a grub, a worm-like animal, eating a tunnel in the wood under the bark (Figure 287), which if not detected would have killed the tree (Figure 288). You may have seen lumber which has been made useless by wormholes made by grubs, a young

stage of beetles; or you have had the leaves of plants in your flower or vegetable garden eaten by grasshoppers. If you have been in an orchard which has not been well cared for, you have found that practically every apple was "wormy" (Figure 289). The "worm" is the young stage of a small moth which flies at night.

FIGURE 286. — POTATO BEETLE.

FIGURE 287. — PEACH-TREE BORER.

These are only a few of the enormous number of ways in which insects harm crops, fruit, and forests by eating them. Give other examples seen by you.

Another group of injurious insects is represented by the plant lice which you sometimes see on house plants. They do much damage to plants in general. And there are the scale insects (Figure 290) which at various times have ruined all of the fruit trees in certain parts of the country.

FIGURE 268.—GROUP OF DYING LOCUST TREES.
Effect of borers and leaf-miners.

The squash bug is another example of this group of insects which does harm by sucking out the juices of

FIGURE 289.—WORM IN APPLE, LARVA OF CODLING MOTH.

plants. The bedbug, of unsavory reputation, is a close relative.

It has been estimated by the Chief of the Bureau of Entomology of the United States Department of Agriculture that the damage done in one year in this country by insects is as follows: Farm crops — cereals, $430,000,000; hay, $116,000,000; cotton, $141,000,000; tobacco, $17,000,000;

Figure 290. — Scale Insects on a Fern Leaf.

vegetables, $200,000,000; sugar, $8,000,000; fruits, $141,000,000; other crops about $55,000,000; making a total of over $1,100,000,000 damage done to farm crops.

In addition, forests and forest products are estimated to have suffered a damage of $100,000,000; products in storage, $100,000,000; insect-borne diseases of man have caused a loss of $150,000,000; domestic animals have been damaged to the extent of $100,000,000; making a grand total of more than $1,500,000,000.

The question is, how can this great loss be lessened?

Problem 2. How injurious insects may be destroyed. —

What do you think would be the best method of destroying insects that eat the leaves of plants? The usual way is to spray the tree (Figure 292) with a poisonous mixture. Paris green mixed with lime and water is frequently used. Arsenate of lead is less apt to injure the leaves and is replacing Paris green to a great extent. To prevent apples from becoming wormy, it is necessary to spray the tree just as the petals fall from the blossom and while the calyx is still open. This is because the moth lays eggs in the blossom and the

FIGURE 291.—TENT CATERPILLARS.
Nest and larvae of apple tree tent caterpillar in wild cherry tree.

poison must get into the cup formed by the calyx before the little larva, or "worm," has a chance to eat its way into the fruit.

Of course insects that live by sucking juices from plants

FIGURE 292. — A MODERN SPRAYING OUTFIT.

are not affected by poisonous sprays. They are usually killed by being suffocated in some way. Dry insect powder may be sprayed over the plant by bellows. This clogs up the breathing holes along the body of the insect. A spray

made of kerosene, soap, and water, another made of whale oil soap, and still another made by pouring hot water over tobacco stems, have been found to be effective in killing these sucking insects. In greenhouses and cold frames which can be tightly closed, tobacco smoke is valuable for killing plant lice.

FIGURE 293. — A BENEFICIAL BEETLE.
Caterpillar of gypsy moth attacked by Calosoma beetle.

Problem 3. How the number of injurious insects is reduced by natural means. — Man's fight against injurious insects might be a losing one if he were not assisted by the many animals that prey upon insects. The big dragon flies which you see soaring in the air, reminding you of miniature airplanes, are on the lookout for flying insects, of which they devour an enormous number. The immature stage (larva) of the dragon fly, living in ponds, have also as their one occupation the destruction of the young stages of other insects.

Ladybird beetles (Figure 294), commonly called "ladybugs," those small round beetles which most of us know, are very helpful in keeping down the increase of plant lice and scales (Figure 295). A number of years ago a species of the ladybird beetle saved the orange industry of California.

The orange groves were threatened with destruction by a scale insect introduced from Australia. As its spread could not be stopped by the ordinary methods of fighting insects, an expert in the study of insects was sent to Australia to find if the scale had any natural enemy. It was found that a certain kind of ladybird beetle fed upon them and thus

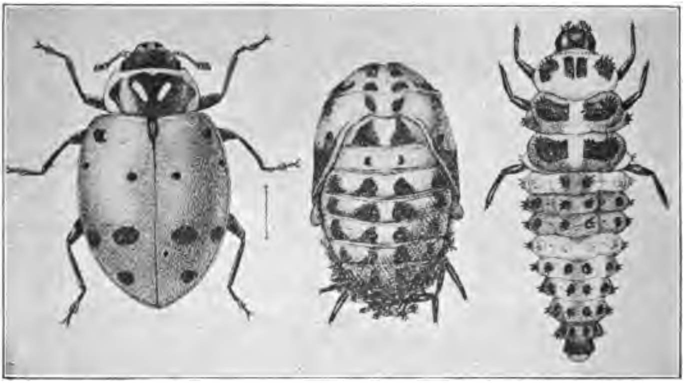


FIGURE 294.—LADYBIRD BEETLE.

kept them in check. Beetles were brought back to California, where they succeeded in saving this very important industry.

In gathering cocoons of moths, it will be frequently found that the interior is filled with a large number of small larvæ or their cast-off skins. The reason for this is that an insect called an *ichneumon* fly, a relative of the wasps, punctured the skin of the moth larva and deposited a number of eggs. These eggs developed into small larvæ which finally completely devoured the body of their host. From these larvæ adult ichneumon flies develop which in turn are ready to attack other caterpillars which are injurious to vegetation. It is thought that parasitic insects like the ichneumon flies

do more to keep in check the increase of injurious insects than all our artificial methods.

Epidemics among insects caused by molds or bacteria sometimes also destroy enormous numbers of them.

It very frequently happens that the year in which some

FIGURE 295. — LADYBIRD BEETLE FEEDING ON SCALE INSECTS.
Note that both larvae and adults feed on scale insects.

insect has been a pest is followed by one in which there are very few of that kind of insect. Can you suggest a reason for this?

Many species of birds live entirely on insects and others

during a portion of the year subsist chiefly on insects. Many birds that are not primarily insect feeders supply a diet of insects for their young. Students of the subject estimate

FIGURE 296. — TOADS EATING CATERPILLARS.

that birds, by destroying harmful insects, each year save crops worth many millions of dollars.

Toads, snakes, and bats are other animals that deserve protection from man because of their value in destroying injurious insects.

SUGGESTED INDIVIDUAL PROJECTS

1. Make a collection showing the various ways in which insects injure plants.
2. Make a collection of injurious insects and give a brief account of the harm done by each kind.
3. Protect the fruit of an apple tree from injury by the codling moth.
4. Make life history cases of a number of injurious insects.

REPORTS

1. The work of the U. S. Bureau of Agriculture in helping the farmer in his fight against insects.
2. An account of the introduction of the gypsy moth, of the harm done by it, and of the efforts made to check it.
3. An account of the life history; of harm done by them; methods used to fight them: potato beetle, cotton boll weevil, codling moth,

Hessian fly, San José scale, chinch bug, grasshopper, brown-tailed moth, army worm, etc.

4. Work of birds in destroying harmful insects.

References for Project XXXI

1. Insects Injurious to the Household and Annoying to Man, G. W. Herrick. Macmillan Company.

2. Insect Pests of Farm, Garden, and Orchard, E. D. Sanderson. John Wiley & Co.

3. Farmers' Bulletins.

4. Farm Friends and Farm Foes, C. M. Weed. Ginn & Co.

5. Birds of Village and Field, F. I. Merriam. Houghton Mifflin Company.

6. Book of Birds, Vols. I and II, Miller. Houghton Mifflin Company.

General Reference Books

Child's Book of Knowledge, Grolier Co., New York.

The Book of Wonders, Presbrey Syndicate, New York.

Wonders of Science, E. M. Tappan, editor. Houghton Mifflin Company.

The Story-Book of Science, Fabre. Century Company.

Modern Triumphs, E. M. Tappan, editor. Houghton Mifflin Company.

Wonders of Physical Science, E. E. Fournier. Macmillan Company.

Field and Forest Handbook, D. C. Beard. Scribners.

Romance of Modern Inventions, A. Williams. J. B. Lippincott Company.

Stories of Useful Inventions, S. C. Forman. Century Company.

Stories of Great Inventions, E. E. Burns. Harper & Bros.

Makers of Many Things, E. M. Tappan. Houghton Mifflin Company.

The Boys' Own Book of Great Inventions, F. L. Darrow. Macmillan Company.

Handicraft for Handy Boys, Hall. Lothrop, Lee & Co.

The Boy Craftsman, Hall. Lothrop, Lee & Co.

Scientific American Boy at School, Bond. Munn & Co.

Harper's Outdoor Book for Boys. Harper & Bros.

Everyday Physics, Packard. Ginn & Co.

The Wonders of Modern Mechanism, C. H. Cochrane. J. B. Lippincott Company.

The Land We Live In, O. W. Price. Small, Maynard & Co.

Uncle Sam's Business, C. Mariott. Harper & Bros.

Commercial and Industrial Geography, Heller and Bishop. Ginn & Co.

With Men Who Do Things, Bond. Munn & Co.

Pioneers of Science in America, W. J. Youmans. D. Appleton & Co.

Famous Men of Science, S. K. Bolton. T. Y. Crowell & Co., New York.

How It Works, A. Williams. Thos. Nelson & Sons.

Romance of Modern Engineering, A. Williams. Seeley Service Company. London.

Great American Industries, W. F. Rocheleau. A. Flanagan Company, Chicago.

A Source Book of Biological Nature Study, Downing. University of Chicago Press.

Chemistry of the Home, Weed. American Book Company.

Chemistry of Common Things, Brownlee, etc. Allyn and Bacon.

Boys' Book of Chemistry, Clark. E. P. Dutton & Co.

Farm Science, W. J. Spellman. World Book Company.

Commercial Raw Materials, Chas. R. Toothaker. Ginn & Co.

Scientific American Reference Book, Hopkins and Bond. Munn & Co.

Measurements for the Household. Bureau of Standards, Washington, D. C.

World Almanac. New York World.

Official Handbook, Boy Scouts of America. Doubleday, Page & Co.

Occupations, E. B. Gowin and A. W. Wheatley. Ginn & Co.

The Story of Iron and Steel, J. R. Smith. D. Appleton & Co.

The Story of the Submarine, Bishop. Century Company.

Practical Physics, Carhart and Chute. Allyn and Bacon.

APPENDIX

I. AVERAGE RISE AND FALL OF TIDE

Places	Feet	Inch.	Places	Feet	Inch.
Baltimore, Md. . . .	1	2	Old Point Comf't, Va.	2	6
Boston, Mass.	9	7	Balboa, Panama . . .	12	6
Charleston, S.C. . . .	5	2	Philadelphia, Pa. . .	5	4
Colon, Panama . . .	0	11	Portland, Me.	8	11
Eastport, Me.	18	2	San Diego, Cal. . . .	3	11
Galveston, Tex. . . .	1	0	Sandy Hook, N.J. . .	4	8
Key West, Fla. . . .	1	2	San Francisco, Cal. .	3	11
Mobile, Ala.	1	6	Savannah, Ga.	6	6
New London, Ct. . .	2	6	Seattle, Wash.	11	4
New Orleans, La. . .	None	None	Tampa, Fla.	2	2
Newport, R.I.	3	6	Washington, D.C. .	2	11
New York, N.Y. . .	4	5			

Highest tide at Eastport, Maine, 218 inches. Lowest tide in United States at Galveston, Texas, 12 inches.

II. SPECIFIC GRAVITY OF SOME COMMON SUBSTANCES

Liquids

Water	100	Alcohol	84
Sea Water	103	Turpentine	99
Dead Sea	124	Milk	103

Solids

Cork	24	Granite	278
Poplar Wood	38	Steel	783
Maple Wood	75	Copper	895
Ice	92	Silver	1.047
Butter	94	Lead	1.135
Coal	130	Gold	1.926
Marble	270	Platinum	2.150
Glass	289		

The weight of a cubic foot of distilled water at a temperature of 60° F. is 1000 ounces avoirdupois, therefore the weight (in ounces, avoirdupois) of a cubic foot of any of the substances in the table above is found by multiplying the specific gravities by 10.

III. COMPARATIVE SCALES OF THERMOMETERS

Centigrade, 100°	Fahrenheit, 212°	WATER BOILS AT SEA-LEVEL	Centigrade, 100°	Fahrenheit, 212°	
95	203		20	68	
90	194		15.3	60	Temperate
85	185		12.8	55	
78.9	174		10	50	
75	167	Alcohol Boils	7.2	45	
70	158		5	41	
65	149		1.7	35	
60	140		0	32	WATER FREEZES
55	131		—1.1	30	
52.8	127	Tallow Melts	—5	23	
50	122		—6.7	20	
45	113		—10	14	
42.2	108		—12.2	10	
40	104		—15	5	
36.7	98	Blood Heat	—17.8	0	ZERO FAHR.
35	95		—20	—4	
32.2	90		—25	—13	
30	86		—30	—22	
26.7	80		—35	—31	
25	77		—40	—40	

IV. COMPARISON OF SOME COMMON UNITS OF MEASUREMENT

1 inch	equals	2.54	centimeters
1 centimeter	"	.3937	inches
1 foot	"	.3048	meters
1 meter	"	3.28083	feet
1 yard	"	.9144	meters
1 meter	"	1.0936	yards
1 mile	"	1.60935	kilometers
1 kilometer	"	.62137	miles

1 liter	equals	1.0567	quarts liquid
1 quart (liq.)	"	.9463	liters
1 quart (dry)	"	1.1012	liters
1 liter	"	.9081	quarts dry
1 gallon	"	3.78543	liters
1 liter	"	.26417	gallons
1 ounce (av.)	"	28.35	grams
1 gram	"	.035	ounces (av.)
1 pound	"	.45359	kilos
1 kilo	"	2.2046	pounds

1 gallon of water	weighs	8.345	pounds
1 gallon	equals	.13368	cubic feet
1 cubic foot	"	7.48052	gallons
1 gallon	"	231.	cubic inches
1 cubic foot of water (4° C.)	weighs	62.425	pounds

1 ton anthracite coal	occupies	40–43	cubic feet
1 ton bituminous coal	"	40–48	cubic feet

V. PREPARATION OF AGAR CULTURE MEDIUM

Place 500 grams, about one pound, of finely chopped lean beef in 1000 cc. of distilled water and keep in an ice box overnight. Strain and squeeze out the juice. Boil the juice for half an hour to coagulate the albumins. Filter and add sufficient distilled water to bring the amount up to 1000 cc.

The use of 3 grams of a standard meat extract, such as Liebig's, to 1000 cc. of water may be used instead of the fresh meat.

Ten grams of peptone should be carefully stirred in and dissolved by boiling.

Add sufficient sodium hydroxide to make the reaction of the broth neutral or slightly alkaline to litmus.

Chop into fine pieces 15 grams of pure thread agar. Dissolve the chopped agar in a small quantity of boiling water. Add this to the hot broth. Filter the broth containing the agar through a filter made of cheese-cloth, enclosing a layer of absorbent cotton. Filtration will be facilitated by first wetting the filter and funnel with boiling water. Sterilize in an autoclave and pour into sterilized Petri dishes.

VI. CLASSIFICATION OF ROCKS AND DIVISIONS OF GEOLOGIC TIME

(Prepared by the U. S. Geological Survey)

The rocks composing the earth's crust are grouped by geologists into three great classes, igneous, sedimentary, and metamorphic. The igneous rocks have solidified from a molten state. Those that have solidified beneath the surface are known as intrusive rocks. Those that have flowed out over the surface are known as effusive rocks, extrusive rocks, or lavas. The term volcanic rock includes not only lavas but bombs, pumice, tuff, volcanic ash and other fragmental materials thrown out from volcanoes. Sedimentary rocks are formed by the accumulation of sediment in water (aqueous deposits or eolian deposits). The sediment may consist of rock fragments or particles of various sizes (conglomerate sandstone, shale); of the remains or products of animals or plants (certain limestones and coal); of the product of chemical action or of evaporation (salt, gypsum, etc.); or of mixtures of these materials. A characteristic feature of sedimentary deposits is a layered structure known as bedding or stratification. Metamorphic rocks are derivatives of igneous or sedimentary rocks produced through mechanical or chemical activities in the earth's crust. The unaltered sedimentary rocks are commonly stratified, and it is from their order of succession and that of their contained fossils that the fundamental data of historical geology have been deduced.

Era	Period	Epoch	Characteristic Life
Cenozoic (Recent Life)	Quaternary	Recent Pleistocene (Great Ice Age)	"Age of man." Animals and plants of modern types.
	Tertiary	Pliocene Miocene Oligocene Eocene	"Age of mammals." Possible first appearance of man. Rise and development of highest orders of plants.
Mesozoic (Intermediate Life)	Cretaceous	Upper Lower	"Age of reptiles." Rise and culmination of huge land reptiles (dinosaurs). First appearance of birds and mammals; palms and hardwood trees.
	Jurassic		
	Triassic		
Paleozoic (Old Life)	Carboniferous	Permian Pennsylvanian Mississippian	"Age of amphibians." Dominance of tree ferns and huge mosses. Primitive flowering plants and earliest cone-bearing trees. Beginnings of backboned land animals. Insects.
	Devonian		"Age of fishes." Shell-fish (mollusks) also abundant. Rise of amphibians and land plants.
	Silurian		Shell-forming sea animals dominant. Rise of fishes and of reef-building corals.
	Ordovician		Shell-forming sea animals. Culmination of the bug-like marine crustaceans known as trilobites. First trace of insect life.
	Cambrian		Trilobites, brachiopods and other sea shells. Seaweeds (algæ) abundant. No trace of land animals.
Proterozoic (Primordial Life)	Algonkian		First life that has left distinct record. Crustaceans, brachiopods and seaweeds.
	Archean	Crystalline Rocks	No fossils found.

The first striking fact in the geological history of climate is that the present climate of the world has been maintained since the date of the earliest, unaltered, sedimentary deposits. The oldest sandstones of the Scotch Highlands and the English Longmynds show that in pre-Cambrian times the winds had the same strength, the raindrops were of the same size, and they fell with the same force as at the present day. The evidence of paleontology proves that the climatic zones of the earth have been concentric with the poles as far back as its records go; the salts deposited by the evaporation of early Paleozoic lagoons show that the oldest seas contained the same materials in solution as the modern oceans; and glaciations have recurred in Arctic and, under special geographical conditions, also in temperate regions at various periods throughout geological time. The mean climate of the world has been fairly constant, though there have been local variations which have led to the development of glaciers in regions now ice free, at various points in the geological scale. That there has been no progressive chilling of the earth since the date of the oldest known sedimentary rocks is shown by their lithological characters and by the recurrence of glacial deposits, some of which were laid down at low levels at intervals throughout geological time.

VII. SOLAR SYSTEM

	Distance from Sun	Radius	Gravity at Surface. Earth = 1	Time of Revolution around Sun
Mercury	35,960,500 miles	1504 miles	.38	88 days
Venus	67,195,600 "	3787 "	.89	225 "
Earth	92,897,400 "	3958 "	1.00	365¼ "
Mars	141,546,600 "	2107 "	.38	687 "
Jupiter	483,327,000 "	43,341 "	2.66	4332 "
Saturn	886,134,000 "	36,166 "	1.14	10,759 "
Uranus	1,782,792,000 "	15,439 "	.96	30,688 "
Neptune	2,793,487,000 "	16,465 "	.98	60,178 "
Sun		432,196 "	27.98	

Moon:—Diameter, 2160 miles; average distance from Earth, 238,862 miles; time of revolution around the Earth, 27.32 days; force of gravity at surface of Moon, one-sixth of the force of gravity at surface of Earth.

VIII. BIRD COUNT IN THE UNITED STATES

(By E. W. Nelson, Chief of the Bureau of Biological Survey, United States Department of Agriculture)

Early in the summer of 1914 the Biological Survey of the United States Department of Agriculture took initial steps toward a count of the birds of the United States for the purpose of ascertaining approximately the number and relative abundance of the different species. This preliminary count proved to be so satisfactory that the Survey repeated it on a larger scale in 1915, and extended it over a still greater area in 1916 and 1917. The results obtained in 1914 have been surprisingly corroborated by those of succeeding year , and the work gives promise of producing, after a series of years, results that, in view of the recognized value of birds to agriculture, cannot fail to be of great value. It has been ascertained through these counts that birds in the agricultural districts in the Northeastern United States average slightly more than a pair to the acre, though in parts of the arid West and on the treeless plains this number dwindles to an average of half a pair, or even less, to the acre.

By far the most abundant birds in the United States are the robin and the English sparrow, but several others are common enough to make their total numbers run well into the millions. The counts so far show that the most abundant bird on farms in the Northeastern States is the robin; next to this is the English sparrow, and following these are the catbird, brown thrasher, house wren, kingbird, and bluebird, in the order named. The densest bird population anywhere recorded is near Washington, D. C., where a careful count showed, in 1915, one hundred and thirty-five pairs of forty species on five acres. Two city blocks, well furnished with trees, in the city of Aiken, S. C., harbored sixty-five pairs on ten acres. These high figures show the important results which will follow from careful protection and encouragement of birds.

INDEX

References are to pages

References are to pages

References are to pages

References are to pages

References are to pages

References are to pages

References are to pages

References are to pages

References are to pages

References are to pages

References are to pages